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"Groundwater: Making the Invisible Visible"

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Editorial

World Water Day is about celebrating, raising awareness and taking action to tackle the global water crisis. A core focus of World Water Day is to support the achievement of UN's Sustainable Development Goal 6: Water and Sanitation for all by 2030. **Every year, the World Water Day highlights a specific aspect of freshwater.** Water is an important piece in the mitigation puzzle but the single most important key to adaptation. Changes in water availability will impact food security, sanitation, health and hygiene and have already proven to trigger water management deficiencies. The pandemic COVID-19 pandemic resurfaced the value of water in our daily life. Not only that, it has also highlighted the investments in the provision of safely managed water, sanitation and better hygiene services must be a key priority in the coming days.

To take action to tackle the water crisis, World Water Day 2022 (22nd March) is going to focus on the theme "Groundwater: Making the Invisible Visible". Groundwater is a vital resource that provides almost half of all drinking water worldwide, including irrigation and industry. It sustains ecosystems, maintains the base flow of rivers and prevents land subsidence and seawater intrusion. Groundwater is an important part of climate change adaptation process and is often a solution for people without access to safe drinking water.

It is our great pleasure to publish 19th volume of SOPHEN Journal on the occasion of World Water Day 2022 with the aim to address WASH issues and will be useful for optimum utilization of knowledge products to raise awareness.

We would like to take this opportunity to express our gratitude to all individuals and all organizations that have joined hands to celebrate the World Water Day 2022.

Thank you all for your kind support.

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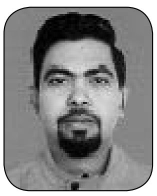

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Content

AN ANALYSIS OF THE EFFECTS OF LAND USE CHANGES ON WATER SYSTEMS IN KATHMANDU VALLEY, NEPAL

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ABSTRACT

Kathmandu is one of the fastest-growing cities in Asia. By creating land use land cover (LULC) maps from 1988, 1998, 2009, and 2018, we found that the size of the built-up area increased by 625% over the thirty years period. However, due to the haphazard and uncoordinated nature of this development, the valley is experiencing severe environmental problems that threaten life and livelihood. Our study analyzes the processes by which land-use changes in peripheral areas of Kathmandu Valley have occurred and the impacts of these changes on both surface and groundwater systems. We used a multi-part methodology combining qualitative and quantitative data analysis including key informant (KII) interviews, household-level semi-structured interviews, and policy analysis, focusing on four different municipalities, to study the effects of land-use changes at both an individual- and valley-level. Minimally regulated land-use changes in peripheral areas impact the environment, economy, and social functioning of the entire valley. As once productive agricultural lands are converted for urban use, groundwater is prevented from recharging sufficiently. Our interview data shows that even the areas that were previously thought to have the most accessible and clean groundwater, such as the regions to the north and east, are quickly being depleted, which profoundly affects household water quality and quantity across the valley.A total of 89 participants were surveyed where56.8% reported that the amount of water available to them has decreased, while 52.3% reported that the quality of their water has degraded. In one municipality, more than 72% reported a perceived change in water quality due to the concentration of contaminants and the use of deeper borewells which extract water from depths where heavy metals are naturally occurring. The same land-use changes that cause groundwater depletion and contamination, also contribute to the increasingly devastating yearly floods during the monsoon, the long-term consequences of which often go overlooked. Despite the rapid urbanization, land use regulation remains weak. The policy as it exists does not allow the government to

impose necessary restrictions on private property, thus proving ineffective in preventing the expansion of the unsustainable urban sprawl. None of these problems—groundwater depletion, degrading water quality, and urban flooding—can be analyzed in isolation. Unless changes are made in peripheral development processes, the effects of unsustainable development will only become more apparent and more disruptive to the functioning of the city.

KEYWORDS

Groundwater depletion, Land use change, Land use policy, Urban flooding, Water quality

INTRODUCTION

1.2 billion people live in water-scarce regions (Aihara et al., 2015). Water access and scarcity are increasingly becoming global issues, intensified by rural-urban migration and climate change. This is exemplified by Kathmandu Valley, Nepal, a rapidly urbanizing region that faces acute water shortage, not because of a lack of available water, but instead due to unregulated land-use change and mismanagement.

Land use patterns in Kathmandu Valley have changed dramatically since 1950. Seventy years ago, the valley population was just 55,000, but the most recent census, conducted in 2022 recorded the population to be 2.99 million. Much of this growth has occurred due to the internal migration of Nepalese from rural districts to urban centers, as they were driven out of their villages by a paucity of agricultural labor and resulting high labor costs, water stress and reductions in crop yield, decreasing farm productivity, reduced benefits of subsistence agriculture, and to escape the rural unrest during the Maoist insurgency, a decade-long civil conflict during which more than 500,000 people were displaced (KCet al., 2017; Haack and Rafter, 2006). Currently, over 44% of valley residents are migrants from other parts of Nepal (Gurung et al., 2017), this trend likely to increase with ongoing urbanization.

Trends of encroachment over arable lands, forests, public lands and various natural resources are rampant these days because of fast growing population, internal migration, unmanaged and rapid urbanization, among others ((MoLRM, 2015).As the population increased, the size of the built-up area expanded in response. Land use land cover (LULC) studies have been conducted to analyze the growth patterns of the changing valley. For example, Haack and Rafter, 2006 showed that from 1978 to 2000 the urban area grew by 450%. Thapa and Murayama, 2009 studied land-use changes in the valley between 1967 and 2000 and found that most of this growth occurred after the 1980s. Kathmandu's peri-urban areas have developed similarly to many other rapidly urbanizing cities in South Asia. As identified by Ishtiaqueet al., 2017, characteristics of this type of urban expansion include unregulated urban development, land speculation, inadequate enforcement of land use policies, poorly maintained city infrastructures, a massive influx of migrants from surrounding rural areas and hinterlands, and gaps in supply and demand for basic services. In Kathmandu's case, because much of the growth has occurred without effective planning, the valley suffers from serious social and environmental issues such as increased water pollution, urban flooding, and problems with water availability and distribution.

Now, although Nepal is one of the most water-rich countries in the world, the median total per capita water consumption in Kathmandu is less than 50 liters per person per day, the United Nations (UN) standard for personal and domestic use (Molden et al., 2018). Over half of this water is sourced from groundwater for domestic, agricultural, and industrial use as water is pumped from deep underground. In 1979, 2.3 million liters a day (MLD) of groundwater were extracted, but by 2011, it had increased to more than 80 MLD, primarily due to high rates of extraction by KUKL, private jar and tanker companies, and the proliferation of household wells (Shrestha et al., 2016). However, while about 21.56 million cubic meters of groundwater is extracted every year (MCM/year), only 14.6 MCM/year are recharged (Tamang, 2016). This deficit has significant impacts on water quality and quantity.

While the previously mentioned LULC studies focus on the patterns of development in Kathmandu, few have analyzed the effects of these changes on the ecosystem and resource availability. Therefore, our paper seeks to address this information gap and to show the effects of land-use changes in peripheral areas of Kathmandu Valley on both surface and groundwater systems by addressing the following questions:1) How has Kathmandu grown over the past 30 years and what factors have contributed to the creation of the urban sprawl? 2) What are the unintended consequences of this haphazard development on water quality and quantity, with a focus on groundwater? 3) What are the gaps in the urban development plans and policies in relation with the water resource and land use?

To answer these questions, we first contextualize Kathmandu's water system and the changes in the valley that have produced the current situation. We then identify key policies that govern land and water use and analyze their effectiveness. We present data from our fieldwork which involves the development of LULC maps and the documentation of the ways people both perceive and are impacted by changing land use through interviews and observation. We conclude with a discussion of the connectedness of land use, water quality, and water quantity to then make suggestions for future sustainable development for Kathmandu Valley.

METHODOLOGY

Study Area

The Kathmandu Valley is an intermontane basin in the central region of Nepal comprising three districts: Kathmandu, Lalitpur, and Bhaktapur, with a total area of 899 km^2. The population of 6 million, concentrated in Kathmandu Metropolitan City, represents 22.77% of the country's total urban population (Rimal et al., 2017). The intensely cultivated walls, averaging 2,800m, rise from a flat valley floor (around 1,300m) of river floodplains and ancient lake and river terraces (Shrestha et al., 2016). Due to this formation, the region has historically been one of the most agriculturally productive areas of the country and has been inhabited for over 2,000 years.

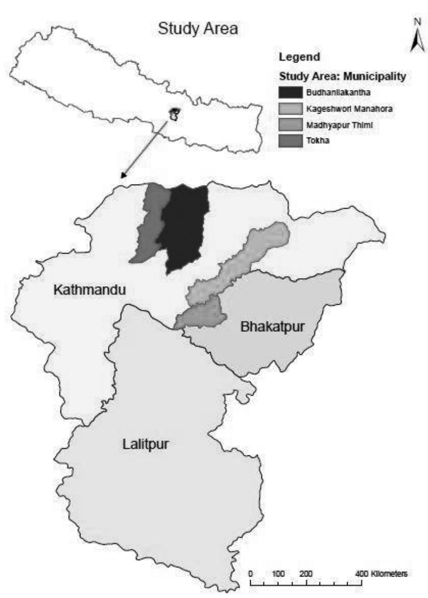

Figure 1. Map of the study area

Our study focuses on four of the valley's 21 municipalities—Budhanilkantha, Kageshwori Manohara, Madhyapur Thimi, and Tokha—which are concentrated in the north and east, and all fall outside the central urban area. Because much of the population growth and urban expansion has happened outside the core city, our study areas were chosen because they are encompassed by the region of most rapid urbanization. While once made up of small agrarian towns, these municipalities have now grown into a connected metropolis, fueled by economic growth and booming real estate market.

In Kathmandu Valley, the peri-urban land, particularly the region encompassed by our study areas, is especially important for the functioning of the urban space due to its hydrogeologic profile. The valley contains two aquifers: a shallow uncontained and a deep contained that are separated by a clay aquitard layer. Because the clay layer is not present in the northeast part of the valley this is the location where most groundwater recharge can take place (Shresthaet al., 2016) such as Budhanilkantha, Mulpani, Gokarnaetc. Additionally, the sandy sediment cover makes it easier to access than the aquifer in the south which is covered by denser sediments. Because of this, groundwater extraction points are concentrated in the north and east, termed as the northern groundwater district, to then supply the urban core. However, while this region supplies most of the groundwater to KUKL wells and private water suppliers, the geological formation also makes it the

most vulnerable to contamination (Shrestha et al., 2016). Changes in land use have exacerbated the natural vulnerabilities ofthe aquifer system with severe consequences that are already felt across the valley.

Development of LULC Maps

LULC maps were created for the entire valley for the years 1988, 1998, 2009 and 2018 using Google Earth Engine with supervised classification with random forest method. Landsat 5 images were used for the 1988, 1998, and 2009 maps and sentinel images were used for 2018. Three different classifications were created: Forest, Built-up Area, and Other, which includes agricultural land, barren land, parks, etc. using images with cloud cover less than 10%. Because our study is primarily concerned with changes in the built-up area, it was not necessary for us to further classify the 'Other' land into multiple categories. The three land cover classes were identified, using a minimum of 100 points for each classification, and defined by the visible indicators in the images. While atmospheric and topographic disturbances could have affected the accuracy of the LULC change detection, the validity of the classification was determined by an accuracy assessment to be over 90% for all four analyzed years, resulting in a statistically significant assessment.

Policy Analysis

A review of all the related legislature and published government plans was conducted. Additionally, interviews with representatives at local, provincial, and national levels, including at each of the study area municipality offices, Kathmandu Valley Development Authority (KVDA), Department of Hydrology and Meteorology (DHM), Department of Irrigation's (DOI) Water Resource Research and Development Center (WRRDC), KUKL, and Kathmandu Valley Water Supply Management Board (KVWSMB) were conducted. This enabled us to understand the policy as it is drafted and then evaluate implementation measures.

Interviews

Each of the four municipalities was visited frequently over a six-month period, and interviews and observations were conducted during each visit. Research participants included two groups of people: institutional actors and household users. These were identified using the snowballing technique, as well as through a literature review of Kathmandu's water policy and existing research. These institutional actors include urban planning and development agencies, civil society organizations and local leaders. The household participants were recruited from within a 1 km radius from the administrative center of each of the municipalities. The 89 individuals represent a diverse group, including men and women, homeowners and tenants, long-term residents and migrants, and a variety of socioeconomic statuses. The dynamic experiences and complex subjectivities of these participants represent the diversity of lived experiences and identities in Kathmandu Valley. This multi-part methodology combining qualitative and quantitative data analysis enabled us to analyze the effects of land-use changes at both an individual and valley level.

POLICY

Land Use Act

On March 19, 2019, the federal parliament endorsed the Land Use Act, based on Article 51 of the 2015 Constitution, to "develop a hygienic, beautiful, well-facilitated and safe human settlement; to enhance a planned and sustainable urbanization of the country, and to achieve sustainable and inclusive economic boost up" (Land Use Act 2015). The foundation of this policy begins with the development of Land Use Plans (LUPs) at all governance levels (federal, provincial, and local) based on the determination of Land Use Zones (LUZs), managed by the Ministry of Land Management, Cooperatives, and Poverty Alleviation (MoLCPA), which is responsible for ensuring that all 753 local governments prepare land use maps for their respective regions.

The LUZs include agricultural, residential, commercial, industrial, mines and minerals, forest, river and lake-reservoir, public use and open space, building materials excavation, cultural and archeological, and other, based on topography, current use, and necessity. Once the LUZ has been determined, the land cannot be used for another purpose outside its classification unless the landowner goes through an application process with the Local Land Use Council and gives clear justification for the need to change. At the local level, these councils must prepare ward-level land use plans for each ward, implement awareness programs on sustainable land use, monitor agricultural land use, and protect public land.

In Kathmandu Valley, KVDA is responsible for the development of the valley-wide LUP and its management. Although this has not yet been implemented, KVDA has categorized wards by their level of development risk sensitivity through the Risk Sensitive Land Use Plan (Tiwari, 2016). They have divided the wards into four zones: residential promotion area, agricultural promotion area, medium alert zone, and high alert zone, each with different bylaws to regulate the construction of buildings, high-rises, and industries. Through this, KVDA hopes to encourage urbanization in some areas while restricting it in others

Water Policy

Although the government of Nepal has passed numerous acts regulating water distribution and quality since the 1950s, water sources remain limited and polluted. Nepal's main legislation regarding drinking water is the Water Resource Act of 1992, an umbrella act that governs all types of water use and management. It created a hierarchy of water use priority, placing drinking water in the most important tier, above water for irrigation and hydropower, and with the Drinking Water Regulation of 1998, drinking water standards were formally regulated (WaterAid, 2005).

One of the most formative of the policies enacted in the last 30 years was the Nepal Water Supply Corporation Act of 1989 which formed an autonomous government-controlled corporation (NWSC) responsible for supplying drinking water. Because the public water system had fallen into disrepair, the NWSC began limiting the piped supply to only a few hours per day. Although they reduced supply hours, the quantity was still so minimal that people were forced to use pumps to bring water into their homes. Due to its inability to supply a sufficient quantity of water, the NWSC was dissolved and reformed in parts, primarily KVWSMB to oversee policy direction and KUKL to manage and operate the Kathmandu Valley's water and sanitation services. Recently, National Water Resources Policy 2077, the first integrated policy in the water sector, has been formulated with a long-term vision for making multi-dynamic, equitable and sustainable development of water resources which has an objective to involve the private sector for water resource conservation and development.

PRESENT STATUS OF THE WATER SUPPLY

Kathmandu Valley's water and sanitation services continue to be operated by KUKL. The water company's piped networks cover 45% of the total valley area, primarily in the urban core, and service 71% of the valley population (Thapa et al., 2018). Although the current demand is 370 million liters a day (MLD), KUKL is only able to supply an average of 115 MLD during the wet season, when most parts of the city get water about every three days, and 69 MLD during the dry, when the frequency of distribution drops to every nine days in some areas (Ojha et al., 2018). They blame their inability to meet demand on a lack of water flowing into the valley, infrastructure problems such as leaks, and poor city planning.

Because most households do not receive enough water to meet their needs, many must rely upon water sources outside of the formal water supply system. These include bore wells (deep borings), shallow wells, *dhungedhara* (traditional stone spouts), community taps, tankers, jars, and rainwater harvesting. (Gurung et al., 2017) found that households use an average of 2.6 sources with 85% using 2 or more. Because of this,

households experience high coping costs including costs of purchasing, storing, treatment, and pumping, as well as non-monetary costs like managing health (Chindarkaret al., 2018;Pattanayakand Yang, 2005).

To reduce the stress on groundwater sources, the government conceived of the Melamchi Water Supply Project, a water treatment and bulk distribution system that will transfer 170 MLD from the Melamchi River to the Kathmandu Valley through a 26.5 km-long tunnel (Domenechet al., 2013). However, due to delays and the inability of the project to evolve with the changing needs of the valley, even after its completion, the region will still have a deficit of around 200 MLD. Therefore, the high rate of groundwater extraction is unlikely to decrease, and households will still bear the responsibility for managing their water sources.

FINDINGS AND DISCUSSION

Land use Change

Our LULCC analysis of the Kathmandu Valley shows that between 1988 and 2018, the size of the built-up increased by 625% (Table 1). This growth is concentrated in the major district centers: Kathmandu Metropolitan City, Lalitpur Sub-Metropolitan City, and Bhaktapur Municipality. Most of the expansion occurred between 1988 and 2009, when the size of the built-up area increased by 415%, though the urban core continues to expand along the major roads in a concentric pattern, significantly altering the cityscape of the valley (Figure 2).

	1988		1998		2009		2018	
	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Built-Up area	2023.74	2.18	4212.81	4.54	11189.34	12.07	14678.71	15.83
Forest	61379.73	66.18	43420.77	46.82	35886.87	38.70	39475.98	42.57
Other (Agricultural, barren, open space, etc.)	29336.76	31.63	45106.65	48.64	45664.02	49.24	38586.84	41.61

Table 1. Summary of the LULC data from 1989 to 2009 in Kathmandu Valley.

Bymapping the biophysical and socioeconomic drivers of migration and analyzing these factors relative to geographic areas of the valley, Thapa and Murayama, 2010 determined that although people are moving to all areas of the valley, much of the infrastructural development is occurring outside the urban core, just as our LULCC analysis shows.

“I have seen many changes in the agricultural land. All the most productive lands have been destroyed. All over the valley, this is true,” one participant reported. Our LULC analysis corroborates this statement; a high proportion of agricultural land in the peripheral areas of the valley has been converted into settled land or divided into smaller plots. As land value increased, landowners, particularly those in peripheral areas, benefited by selling their land to developers, especially if they were able to sell marginal, non-irrigated, sloping land that was not agriculturally productive. However, the land in these peripheral areas had been essential for its ability to store water due to its sandy composition which would regulate runoff and facilitate groundwater recharge.

Instead of sandy soil, the land is increasingly covered in concrete, so water does not percolate through the ground to the aquifers, but instead flows directly to the rivers, contributing to the annual urban flooding. This is exacerbated by other changes in land use such as the switch from rice to vegetable cultivation or increasingly, leaving land fallow. Because land without a cover crop does not hold water, it acts like pavement during the deluges of the monsoon and disrupts the recharge cycle.

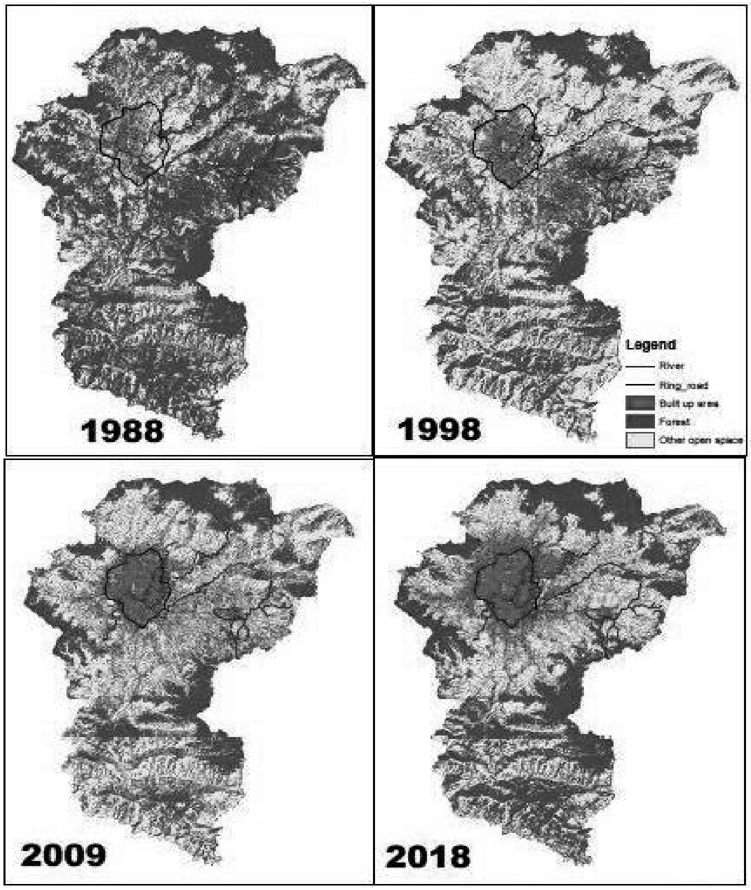

Figure 1. LULC maps of Kathmandu Valley

The unplanned and poorly regulated development has had significant environmental consequences. As once productive agricultural lands are converted for urban use, groundwater is prevented from recharging sufficiently. "The reality is, the faster Budhanilkantha grows," a rainwater harvesting and water filtration expert explains, "the worse the groundwater situation is going to be."

Effects on Groundwater Quantity

"In general, Mulpani [a ward in KageshworiManohara municipality] and those areas [in the north groundwater district], are supposed to be groundwater abundant in terms of their geological formation, depth of aquifer, and the information we have so far," describes a researcher at the International Water Management Institute (IWMI). However, our interview data suggests that even the areas that were previously thought to have the most accessible and clean groundwater, such as the regions to the north and east, are quickly being depleted, which profoundly affects household water quality and quantity across the valley.

"The name 'Mulpani' means source of water," a Kageshwori Manohara resident said, "But even here, there is none." 56.8% of survey participants across our four study areas reported that the amount of water available to them has decreased. Another resident said that he chose his neighborhood specifically because he had heard it was water abundant, only to find this was not the case. He says he is disappointed that he migrated from a district where he was so conscious about water conservation, to living in Kathmandu where he feels as though this is not happening.

Other participants had similar feelings about source conservation and changing land-use patterns. One resident of Budhanilkantha said, "I am worried. Just ten years ago, there was greenery here. Now there is none. There was water everywhere. Now, those sources have already dried." The presence of drying wells and spring sources suggests that the effects of urbanization are already being felt. The IWMI researcher has concluded that due to the expansion of the built-up area, "perhaps pathways for recharging the aquifers might have been blocked or reduced. As a result, they are not getting enough water and they dry quickly." However, the valley lacks studies to the necessary level on the hydrogeologic formation, so it is not possible to directly correlate our participant reports with a physical phenomenon; but these local perceptions are essential in crafting sustainable solutions.

Effects on Groundwater Quality

"I have so much tension, managing these basic things. I can't even use the water in my well because it is so red! It turns my clothes brown and it makes my hair dry. I could take the time to filter it, add chemicals, make sure it is good, but when I get home from working all day, I don't like to spend my time that way" (personal communication, December 5, 2019).

This is a common sentiment across the valley. 52.3% of our participants reported that the quality of their water has degraded, especially in Tokha Municipality, the most urbanized of our study areas, where more than 72% reported a perceived change in water quality.

There are two reasons for this. One is that as people are forced to use deeper borewells to adapt to the lowering water table, they are increasingly extracting from depths where heavy metals and other substrates including ammonia, manganese, iron, and nitrates are naturally occurring. The depleting water level concentrates these compounds and causes them to become hazardous. Additionally, water in the confined aquifer, which previously had little connection with surface water, now contains indicators of biological contamination which suggests that pathways have been created, likely due to poor well construction.

While biological contamination poses widespread and immediate threats, many other contaminants such as elevated levels of heavy metals also pose health hazards and are economically costly. Many high-volume extractors, such as private tanker companies, expressed concern about the quality degradation. One company owner said that they pass the water through a filtration system that uses gravel, sand, and carbon, but even with this treatment process, they are still unable to attain the quality levels designed for drinking water by KVWSMB. Additionally, the purification substrates and the pipes that connect the extraction site to the tankers must be cleaned or completely replaced every six months due to the high level of iron, causing him to question the longevity of the system.

The same land-use changes that cause groundwater depletion and contamination, also contribute to the increasingly devastating yearly floods during the monsoon. Although policies exist to regulate the development of the riverscapes, interference with the natural flow of the rivers continues to happen due in part to the complicated and fragmented bureaucratic structure of the many government bodies responsible for different aspects of urban planning like road development and water system management. The polluted flood water inundates shallow wells, tube wells, spring sources, and household underground water storage tanks, exacerbating the already dangerous levels of contaminants.

Policy

Despite the rapid urbanization and valley-wide problems with water quantity and quality, policy implementation and regulation remain weak. The policy as it exists does not allow the government to impose necessary restrictions on private property, thus proving ineffective in preventing the expansion of the unsustainable urban sprawl. Additionally, execution of the plan outlined by the Land Use Act remains limited and the LUZ maps have not yet been created, so none of the local bodies can carry out any land use regulation under the Land Use Act.

KVDA's implementation of these restrictions has been largely unsuccessful in the valley due to structural barriers. One of these is the unbalanced urban structure within the valley. Most economic activities are concentrated in Kathmandu while peripheral municipalities are primarily rural. This makes valley-wide policy drafting and implementation difficult. Additionally, KVDA has little connection with the top-level ministries, which they say has resulted in uncoordinated policy formulation and implementation. Further, lack of integrated land use management policy remains as the challenges as identified in KVDA's Risk Sensitive Land Use Plan. These issues are furthermore exacerbated by the weak administrative, technical, and financial capacity of many of the municipalities.

The lack of land use regulation impacts Kathmandu's water supply. Although the legislation exists, the supply remains insufficient, and the quality continues to degrade. This is partially due to a lack of policy implementation and partially because in both policy and practice, water systems and the factors that impact them, such as land use, continue to be managed as separate entities.

TECHNICAL AND SUSTAINABLE INTERVENTION

While many try to frame the water problems in Kathmandu Valley as a result of climatic changes and over-population; in reality, water insecurity is an environmental problem as well as a technical and legislative one. The problem withimplementation of existing land use policy and the sustainable interventions is due to lack of a coordinated institutional framework to manage the environment and natural resources in Kathmandu Valley.

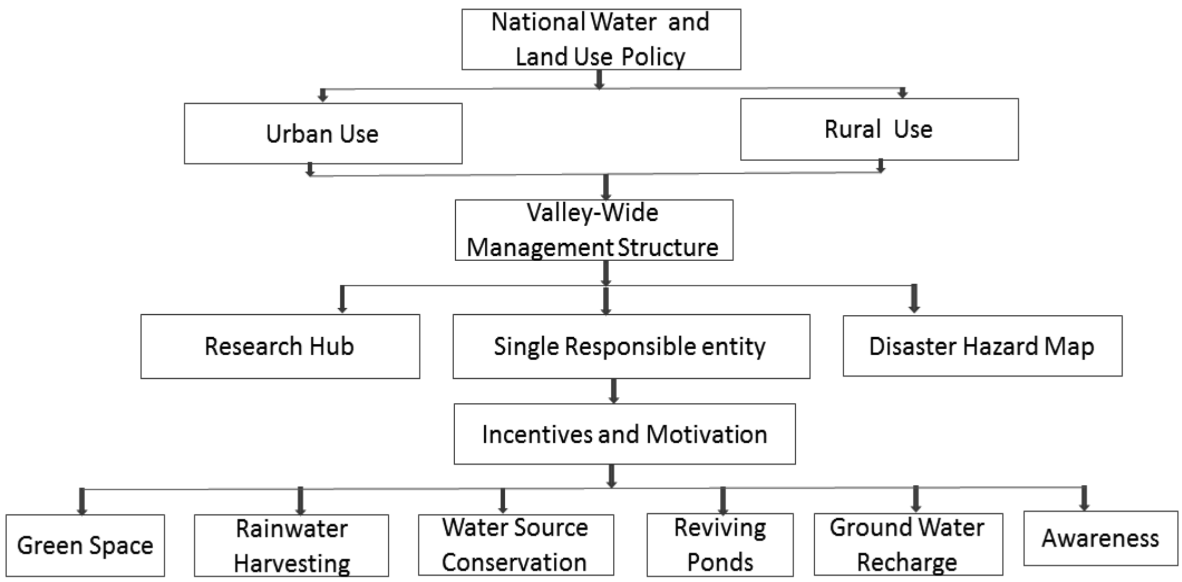

Figure 3. Framework for sustainable intervention

As a way to address this and based on the identified policy gaps, we have developed an alternative management structure as an intervention to promote future sustainable urban development in Kathmandu Valley (Figure 3). This begins with the development of a combined National Water and Land Use Policy with separate provisions for rural and urban areas. This policy should include stipulations for the formation of a valley-wide management structure to create a single responsible entity and streamline government departments. This management structure should have these primary roles: 1) Oversee all water and land use research 2) Produce valley-wide land use, groundwater, and hazard maps 3) Coordinate policy implementation and administration 4) Incentivize and motivate individuals and communities to adopt sustainable practices.

To guide future policy directions, valley-wide maps that detail geography, land use, and hazard vulnerability must be created. The KVDA has shown through its Risk Sensitive Land Use Plan which is developed with due consideration of multi-hazard risk sensitivity and climate change stimuli, that every part of the valley should not be subject to the same level of regulation. Areas that are highly prone to flooding or that are in zones important for groundwater recharge should be more tightly regulated. Because research institutions across the valley have been gathering data on individual components of these maps, a hub for sharing this knowledge should be created. This research intuitional framework should contain a review board that would enable the government to manage and publicize the topics and quality of all research projects and would help fill the gaps that currently exist in environmental data that can prevent significant research from being carried out. This authority could implement tax breaks, a method used worldwide to promote environmentally friendly infrastructure, and through building codes.

CONCLUSION

The present situation makes it especially important to understand the dynamics of LULC change processes and their effects. There has been drastic increase in the urban sprawl in last 30 years, which has led to cause groundwater depletion, contamination and has also contributed to urban flooding.Minimally regulated

land-use changes in peripheral areas impact the environment, economy, and social functioning of the entire valley. The choices that are made with natural resources now, the way the valley periphery continues to be developed, the constant demand for more water forcing deeper borings, all mean that unless action is taken, the water that flows through and under Kathmandu will not only remain contaminated and limited but will eventually become virtually unusable.

As we have shown, Kathmandu's water situation cannot be analyzed in isolation. Unless changes are made in peripheral development processes, the effects of unsustainable development will only become more apparent and more disruptive to the functioning of the city. The lack of coordination has been seen as the biggest impediment to addressing the gaps that currently exist between land use regulation and the impacted sectors which is apparent with the most widespread consequences in Kathmandu Valleywhere local, provincial, and national bodies all have competing legislature. Until strongcombinedpolicy is in place, sustainable technical interventions cannot be carried out effectively. Systematic changes are especially important now. If federalism plays out the way it was envisioned, cities across the country will begin to urbanize. Therefore, without the proper policy and knowledge systems, there is nothing to stop these areas from growing similarly to Kathmandu.

REFERENCES

Aihara, Y., Shrestha, S., Kazama, F., &Nishida, K. (2015). Validation of household water insecurity scale in urban Nepal. *Water Policy, 17*, 1019-1032.

Chindarkar, N., Chen, Y. J., & Gurung, Y. (2018, December 1). Subjective Well-Being Effects of Coping Cost: Evidence from Household Water Supply in Kathmandu, Nepal. *Journal of Happiness Studies*.

Domenech, L., March, H., &Sauri, D. (2013). Contesting large-scale water supply projects at both ends of the pipe in Kathmandu and Melamchi Valleys, Nepal. *Geoforum, 47*, 22-31.

Gurung, Y., Zhao, J., KC, B. K., Wu, X., Suwal, B., & Whittington, D. (2017). The costs of delay in infrastructure investments: A comparison of 2001 and 2014 household water supply coping costs in the Kathmandu Valley, Nepal. *Water Resources Research, 53*, 7078-7102.

Haack, B. N., & Rafter, A. (2006, December). Urban growth analysis and modeling in the Kathmandu Valley, Nepal. *Habitat International, 30*(4), 1056-1065.

Ishtiaque, A., Shrestha, M., & Chhetri, N. (2017). Rapid Urban Growth in the Kathmandu Valley, Nepal: Monitoring Land Use Land Cover Dynamics of a Himalayan City with Landsat Imageries. *Environments, 4*(72), 1-16.

KC, B., Wang, T., & Gentle, P. (2017). Internal Migration and Land Use and Land Cover Changes in the Middle Mountains of Nepal. *Mountain Research and Development, 37*(4), 446-455.

MoLRM. (2015). *Land Use Policy.*Ministry of Land Reform and Management, Government of Nepal, Singhdurbar, Kathmandu.

Molden, O. C., Khanal, A., & Pradhan, N. (2018). The pain of water: a household perspective of water insecurity and inequity in the Kathmandu Valley. *Water Policy*, 1-16.

Ojha, R., Thapa, B. R., Shrestha, S., Shindo, J., Ishidaira, H., & Kazama, F. (2018). Water Price Optimization after the Melamchi Water Supply Project: Ensuring Affordability and Equitability for Consumer's Water Use and Sustainablity for Utilities. *Water, 10*(249), 1-13.

Pattanayak, S. K., & Yang, J. C. (2005). Coping with unreliable public water supplies: Averting expenditures by households in Kathmandu, Nepal. *Water Resources Research, 41*, 1-11.

Rimal, B., Zhang, L., Fu, D., Kunwar, R., &Zhai, Y. (2017). Monitoring Urban Growth and the Nepal Earthquake 2015 for Sustainability of Kathmandu Valley, Nepal. *Land, 6*(2).

Shrestha, S., Semkuyu, D. J., & Pandey, V. P. (2016). Assessment of groundwater vulnerability and risk to pollution in Kathmandu Valley, Nepal. *Science of the Total Environment, 556*, 23-35.

Tamang, M. S. (2016, Fall). Water Connection: Everyday Religion and Environment in Kathmandu Valley. *Himalaya, 36*(2), 82-89.

Thapa, B. R., Ishidaira, H., Pandey, V. P., Bhandari, T. M., & Shakya, N. M. (2018). Evaluation of Water Security in Kathmandu Valley before and after Water Tranfer from another Basin. *Water, 10*(224), 1-12.

Thapa, R. B., & Murayama, Y. (2009). Examining spatiotemporal urbanization patterns in Kathmandu Valley, Nepal: Remote sensing and spatial metrics approaches. *Remote Sensing, 1*, 534-556.

Tiwari, B. K. (2016). Policies and Initiatives of Kathmandu Valley Development Authority

(KVDA) towards Implementation of Sustainable Development Goals [PowerPoint

slides]. Retrieved from *https://www.unescap.org/.*

WaterAid. (February 2005). *Water Laws in Nepal: Laws Relating to Drinking Water, Sanitation, Irrigation, Hydropower and Water Pollution.*

Zurick, D. (2010, October). Kathmandu (Kathmandu Valley, Nepal; 1975-2010). *Journal of Cultural Geography, 27*(3), 367-378.

RAISE EFFICACY OF GROUNDWATER AS WATER REQUIREMENT IS EVER-INCREASING

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ABSTRACT

Groundwater, which plays a complementary role in the entire water resources use is underestimated or overlooked in many aspects as it is hidden or invisible, leaving an impression of "out of sight, out of mind". In fact, it is a finite resource working with no border, which in present context has overstretched under the circumstances of increasing urbanization and industrialization, population pressure, climate change impacts and emergency water demands. Technological, social, environmental, economic and partnership are the factors of attention for safe and secured use of groundwater for present and future needs. A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis conducted on the aspect as pointed out by the theme of World Water Day this year indicates that in Nepal the National Water Resources Policy and Strategy revised in 2021, several advancements made by Groundwater Resources Development Board Nepal, and call of the UN International Decade for Action on Water for Sustainable Development 2018-2028 should be taken as supportive steps in availing increasing opportunities for related sectors to transform 'groundwater' from an invisible to a more visible and accountable resource; and to work rightly for its optimum utilization and benefits.

KEYWORDS

Aspects Affecting Groundwater,Invisible to Visible,SWOT Analysis Nepal,Water Resources

BACKGROUND

Water scarcity already affects four out of every 10 people as per World Health Organization (WHO). This is the reason Mr. António Guterres, Secretary General of the United Nations has once called the nations

saying “Let us commit to intensifying efforts to truly valuing water, so all may have equitable access to this most precious resource”. UN-Water insimilar way takes a lead role in global observance of World Water Day yearly since 1994, emphasizing on specific themeevery year so as to advocatethe potential challenges within the water sector and to raise concerns about countries’sustainable development predominantlybeing affected bywater-related actions. UN General Assembly in 2016 has declared an International Decade for Action on Water for Sustainable Development, 2018-2028 to energize existing programmes and projects, which has opened more avenues for international, regional and national collaborations to accelerate efforts towards working on water-related challenges,and uprisingpressure on water resources and ecosystems at the face ofincreasing risk of droughts and floods (7). Groundwater, which is more of a resilient resource of fresh water complements tothe entire water resources; however, it is often underestimated or overlooked as it is hidden or invisible, leaving an impression of “out of sight, out of mind” (6). This year, it is thesecond time (in the entire period of 28 years since 1994!), that the groundwater has reemerged into the thematic call of World Water Day with the theme “Groundwater: Making the Invisible Visible”; as it was first time appearing in 1998 with the theme “Groundwater – The Invisible Resource”.In fact, groundwater being a finite resource working with no boarder, has been overstretched in the present context under the circumstances of increasing urbanization and industrialization, population pressure, climate change impacts and emergencies (1,3). Therefore,it isnever late to take appropriate steps to further refine relevant plans, programmes and policy decisions at different levels. As well as to implement actions to transform ‘groundwater’ from an invisible to a more visible and accountable resource and lastly,to work rightly for its optimum utilization and benefitswith due consideration to theever-demanding issues ofequity, human rights, dignity and decent-livelihoodglobally(6).

GLOBAL PROSPECTIVE OF GROUND WATER

Global summation of freshwater as available is categorized as glaciers 68.7%, groundwater 30.1%, surface water 0.3% and water in various other forms 0.9%. It is estimated that total volume of fresh groundwater stored on earth is between 8 and 10 million km^3. Total abstraction of groundwater worldwide in 2010 was approximately 1000 km^3 per year, which is approximately one fourth of all freshwater withdrawals globally. Of all groundwater abstracted, 67% was used for irrigation, 22% for domestic purposes and 11% for industry. Groundwater providesalmost 50% of all drinking water worldwide and 43% of all consumptive use of water for irrigationin agriculture (6). Groundwater,conjunctively with surface water and rainwater,is used for variouspublic needs such as water supply and wastewater management, irrigation and agricultural productivity, industrial and institutional water requirements, environmentand ecosystem restoration, recreational water use, climate change adaptation and mitigation, and coping with emergency/disaster situations(1).Quantity, quality, accessibility and reliability are regarded as groundwater’s paramount indicators to guide usin the process ofits planning, design, and development, as well asin controlling theoperational efficiency of water systems.Insufficient groundwater recharge, declining water table, increasing risk of external and natural contamination of aquifers, land use activities,andsea water intrusion are commonobstacles that often hinder the achievement ofsuch indicators (6).Understanding of groundwater system using investigation and aquifer mapping tools, quantity and quality management/control using scientifically proven techniques, maintaining operational balance between water withdrawal and recharge, and going into integrated water use practices help in withholding system sustainability, contributing to thesocietal livelihood and benefits, and bettersecuring this resource for future generations (4).

DIFFERENT ASPECTS AFFECTING GROUNDWATER MANAGEMENT

Social, economic, environmental, technical, and governance aspectsare equally important while dealing with way outs to overcome challenges, and to reinforce key strengths in the process of sound development and management of groundwater resource. ‘**Social**’ aspects are related with involvement of people, gender balance, identifying marginalized group, stakeholders’ involvement, participatory approach; and raising

awareness. '**Economic**' aspects are related with economic value established for groundwater through its benefits and cost analysis; taking it as a finite and limited resource so to pay for public and individual abstractions, necessity to pay by the polluters of the groundwater; wastewaters to undergo for treatment, recycle and reuse prior todisposal; and equitable and efficient groundwater management with increased 'willingness to pay' by the users. '**Environmental**' aspects are related with groundwater availability in quantity and quality,proportionate use of groundwater for water, energy and food security, ecosystem and biodiversity support, wetland management and maintaining base-flow in downstream rivers, contaminant/ pollutant transport; surface runoff responsible for water percolation and recharge; water and wastewater treatment and reuse; and water sufficiency for human livelihood and health. '**Technical**' aspects are related with knowledge management and technology transfer/use, strictness in applying technical/engineering ethics in groundwater utilization, technical capacity building at different levels, ground water investigation, survey and information management, inventory and record keeping, service zoning to protect depletion and working with land use changes, and optimizing complementary use of groundwater and surface water sources. Finally, '**Governance**' refers to institutional strengthening, long-term planning, updates of policy, strategy, regulation and laws, enhancing policy dialogue and political commitment, expanding partnership and collaboration among government and non-government stakeholders, inter-sector involvement and co-working, and financing for groundwater development and use.These all are the concerns contributing to the sustainable use of groundwater (3,5,6).

GROUNDWATER SCENARIO IN NATIONAL CONTEXT

With varying physiography and subsurface geology, Nepal has a rich groundwater resource on the part of its southern plain compared to its other mountainous regions. In the southern plain groundwater has sufficient capacity to meet the demand for water supply and irrigation. Whereas, in the mountainous parts, groundwater is limitedly used in conjunction with surface water sources for various purposes (4). Increasing water demand along with ever increasing population pressure, insufficient governance and regulation, limited technology and engineering use/compliance, and environmental degradation and climate change impacts have heavily exaggerated the process of optimizing utilization and sustainable development of groundwater resource (3,4,5).National Water Resource Act 1992, National Water Resources Rule 1993, National Water Resources Strategy 2002, National Water Plan 2005, and National Water Resources Policy (revised in2021) are all the government's authorized document collectively providing guidance for working towards increased sustainability in the development and use of water resources including groundwater (8,9,10,11,12). Also, Groundwater Development Board established in 1976 is working together with other related sectors of the country and providing supports mainly for technical investigation of aquifer and survey for groundwater potential; implementation of shallow and deep aquifers-use in irrigation and drinking purposes in Terai plain; spatial monitoring of water level fluctuations, estimation of water reserve in aquifers, and water quality variations. Different studies under this Board categorized as hydrogeological, geophysical, and hydro-chemical studies help providing information, statistics and knowledge on groundwater development and management on a regular basis. Development of an updated national action plan based on recent revised national water resources policy will be highly valuable to assist different water sectors and stakeholders involved in waterworks, including groundwater in this current context of SDGs (11). A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis for heightening groundwater's overall importance and its use-efficacy in Nepalese context, as per reviews in the literatures as listed, has been worked out as follows.

Strengths:

- Nepal has huge potential of groundwater resources and the countryhas started using it from the 70's.
- Proportion of irrigation to domestic uses of ground water is around 70:30 (as per Nepal Water Plan 2005).
- The country has well established Act, Rules, Strategy, Plan, and Policy on water resources inclusive of groundwater.
- Ground Water Development Board established in 1976 is a common platform for gaining synergy

in coordinated actions amongst relevant sectors.

- Terai being a part of the larger Ganges basin has good renewable groundwater reserve, and has enough scope to expand its utility.

Weaknesses:

- A good groundwater governance is often lacking in absence of expanded investigation, survey and research to understand aquifer characteristics and for strengthening groundwater database nationally.
- Transformation of science and technology related to groundwater exploration, development and utilization into its policy, plans and actions for increased effectiveness is not enough.
- Groundwater regulation is not stringent enough to control rampant use of this limited resource, both by public and private users, for domestic needs in the rapidly expanding urban environment and for meeting the existing irrigation gaps in Terai; including paying less attention to promote artificial recharge of groundwater to the extent possible.
- Mountains and valleys have limited groundwater resources to meet ever increasing water demand due to small and isolated basins, and varying geologic, physiographic and climatic conditions.
- Holistic approach to linking groundwater with irrigation, agricultural productivity, food security, poverty reduction; and similarly with water supply, sanitation, hygiene and health. Hence, to improve peoples' socio-economic conditions and livelihood contributing to the sustainable development goals (SDGs) is not prominently evident in national policies and actions.

Opportunities:

- National water Resources Policy recently revised in 2021 has opened ample avenues to revisit national plans and activities on groundwater management, use of science into practice, and for referring to the several external aspects of considerations.
- Feasibility of large-basin management and conjunctive use of surface and groundwater could be increasingly perceived under the jurisdiction of the newly formed provincial governments with having their respective water strategy, policy and plan.
- SDG era currently is approaching to its midway, so with the lessons learnt so far, it is high time now to reorganizewater use practices and make groundwater more visible in holdingits stake within the entire water resources compared tothe past so to work genuinely for 'no one is left behind' with respect to water.
- Strengthened coordination, collaboration and networking among water stakeholders at different levels would be more facilitatedunder the current circumstances of UN declaration of International Decade for Action on Water for Sustainable Development, 2018-2028.
- Knowledge management platforms are increasingly coming up at global and regional levels; such platforms for groundwater science-base and its sustainable use could be more helpful in technology transfer and building national institutional and human resources capacity.

Threats:

- Climate change often results into extreme weather events –'dry will be much drier and wet will be much wetter'. There are increasing risks that ground water storage shrinks in the drier periods with declining water (water decline in larger urban areas are far beyond the recovery from natural recharge),whereas water quality gets more deteriorated in wetter periods due to recharge from excessive surface runoff and pollutants transport.
- Covid-19 pandemic has threatened overall development of the country and implementation of 15thnational plan of the government 2019-2024. As this plan calls foran effective coordination among related sectors and at the three levels of the government for optimizing water resources use to fulfill ever rising water demands.
- Capacity buildingactions in the groundwater management issuesif not timely accelerated in the country will again not help result into increased and effective use of this hidden but highlypotent resource for various demands.

- In recent years, the pace of yearly expenditures on infrastructures and developments are less than as planned as it is often reported by the media, such slackness may also effect to the expanded national activities planned for water resources development and management including groundwater in the coming years.
- Seriousness in multi-stakeholders' support for increasing water shortages leading to the quantity, quality and reliability uncertainties as well asregulation shortfalls in practice ifnot heightened necessarily, will not bring much changes in sustainable development of groundwater resource.

CONCLUSION

Groundwater is a hidden and invisible resource globally; some countries are more advanced to make this resource significantly visible and accountable going deeply into its science, technology and socio-economic aspects, whereas others could not have made much progress so far. This years' theme for World Water Day (viz. Groundwater: Makingthe Invisible Visible) is meant to raise the profile high, expand studies to understand aquifer's geohydrology and storage limit, balance between yearly abstraction versus declining water table, optimization of groundwater use, water quality control, and study on socio-economic aspects related to the groundwater; so that there will be more support to sustainable use and appropriate development of this finite water resource in coming yearswith appreciating the fact that it is not a free and unlimited gift of the nature. In the context of Nepal, leadingand expanded role of Groundwater Development Board for enhancedsector coordination, policy decisions, capacity building, technology transfer, strict enforcement of regulations, awareness raising and peoples' participation, fund raising, and optimizing use of groundwater in conjunction with other surface water sources for different purposes is fundamental. By making effective use of several national and international recent calls for action related to water, this country could truly benefit a lot in coming years as it is very rich in water resources including groundwater as a potential portion, butincreasingly facing challenges with groundwater being subjected to overuse and depletion.

REFERENCES

1. Velis M., Conti K. I., and Biermann F. (2017). Groundwater and human development: synergies and trade-offs within the context of the sustainable development goals.
2. Foster S., Eichholz M., Nlemd B., and Gathu J.(2020). Securing the critical role of groundwater for the resilient water-supply of urban Africa.
3. Shrestha A. Groundwater policy and groundwater dependencies: reflecting on the evolving socio-environmental dynamics in peri-urban Kathmandu valley, 2019
4. Kansakar D. R. (2006). Understanding groundwater for proper utilization and management in Nepal.
5. Yadav S. K. (2018) Groundwater challenges, governance, and management in Nepal.
6. Smith M., Cross K., Paden M., and Laban P.(2016) Managing Groundwater Sustainably. IUCN publication, Gland, Switzerland
7. International Decade for Action on Water for Sustainable Development, 2018-2028. (2018). United Nations, https://www.un.org/en/events/waterdecade/background.shtm
8. Water Resources Act.(1992). Ministry of Water Resources, HMG Nepal
9. Water Resources Rules.(1993). Ministry of Water Resources, HMG, Nepal
10. Water Resources Strategy Nepal,(2002). Water and Energy Commission Secretariat (WECS), HMG Nepal
11. National Water Resources Policy Nepal.(2021). Energy, Water Resources & Irrigation Ministry, Government of Nepal
12. National Water Plan(1995). Water and Energy Commission Secretariat (WECS) HMG Nepal

23.15thNational Plan, 2019-2024. (2019). National Planning Commission, Government of Nepal

CHARACTERIZATION OF FAECAL SLUDGE AND DESIGN OF FAECAL SLUDGE TREATMENT PLANT IN DHULIKHEL MUNICIPALITY

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ABSTRACT

Nepal is progressing on the sixth Sustainable Development Goal by declaring the end of open defecation all over the country. But, impacts on human health and the environment associated with lack of sewer treatment facilities and unsafe disposal of faecal sludge are still prevailing. This study involves characterization of faecal sludge from septic tank in Dhulikhel Municipality and design of faecal sludge treatment plant. Field observations, discussions with local authorities and analysis of secondary data were used to assess the faecal sludge management practices in Dhulikhel municipality. More than 80% of households are dependent on onsite sanitation service where desludging service is provided by a single vehicle within the municipality with a desludging rate of 4-5 households per week. Lab analysis were carried out in the laboratory of Department of Environmental Science and Engineering, Kathmandu University, Dhulikhel. It is found that the average concentration of Total Solid, Total Suspended Solid and Total Volatile Solid were 35,506 ± 17,450 mg/L, 28,214 ± 13,806 mg/L, 15,296 ± 7,184 mg/L, respectively. Also, average concentration of BOD, NH_3-N, Phosphorus (P), Potassium (K) and Total Kjeldahl Nitrogen (TKN) concentrations were 674 mg/L, 190.53 ± 81 mg/L, 24.21 ± 11 mg/L, 178.26 mg/L and 105 mg/L, respectively. The characterization of faecal sludge samples indicated the variation of concentrations within a septic tank with respect to depth. With a purpose of treating 6m^3 of faecal sludge collected per day in Dhulikhel, Screener, Settling/Thickening tank, Anaerobic Baffled reactor, Planted Drying Bed and Planted Gravel filter are designed which will have efficiency removal of 60-80% of BOD and TS. Treatment of faecal sludge will not only protect the water sources from potential contamination due to current practices but create possible opportunities for circular economy using biosolids rich in N, P and K as fertilizer. Political willingness and good governance will only ensure the sustainable management of sanitation for all.

KEYWORDS

Characterization, Desludging service, Faecal Sludge, Treatment Plant

INTRODUCTION

Rapid urbanization has been causing serious challenges on the health and environmental status in the developing countries day by day. Around 2.7 billion people were served by on-site sanitation (OSS) technologies worldwide in the year 2014 and that number is expected to grow to 5 billion by 2030 (UNICEF & WHO, 2015). The practices of OSS technologies are gaining popularity worldwide that has resulted in reduction of open defecation but still the consequences on health and environmental impacts have not shown a considerable change.

According to the census 2011, 30% of urban population has toilets connected to the sewer system while 48% have septic tanks in Nepal (CBS, 2011). Most of the faecal sludge (FS) generated every day is disposed untreated into the nearby lands or streams due to the fact that either the existing treatment plants are designed to treat wastewater (WW) only or the FS produced exceeds the capacity limit of the treatment facilities available. In Nepal, OSS is predominant because it is cheaper than the sewerage system and is affordable even by the low-income people. Although Faecal Sludge Management (FSM) can be less expensive, it is in reality much more complicated than a sewer system. In addition to the diversity of sludge containment types, it requires the active and complex management of personal, financial, political, legal, and socio-cultural interactions along the entire service chain (Strande et al., 2018). Therefore, FSM is an important aspect of sanitation, which must be included in the development of any sanitation plan.

The quantities of FS generated and the typical FS characteristics are difficult to determine due to the variety of onsite sanitation technologies in use, economy, climatic factor and desludging practices (Niwagaba et al., 2014). As a result, lack of quantification and characterisation of faecal sludge has resulted in insufficient and improper basic outlines to create a proper plan for safe disposal of FS.

Dhulikhel is a growing city, nearest to the capital, and a popular tourist destination which has the possibility of rapid urbanization.The existing treatment processes for Dhulikhel Municipality are not fully equipped. According to the (ENPHO, 2020), almost 84% of the population are equipped with OSS. The proportion of FS that is being unsafely managed is 49%. However, the sum of the FS stored in a safe containment which has not gone through any desludging/emptying process till now and uncollected amount of FS during the emptying process holds a significant proportion (25%), which has been considered as safely managed, but needs proper treatment. Thus, in total 74% of FS generated in Dhulikhel municipality needs proper treatment. Lack of available FS data (quality and quantity), and improper disposal of FS requires an immediate solution. Thus, FS is quantified, characterized and FSTP is designed to treat the FS generated within Dhulikhel Municipality.

MATERIALS AND METHODS

Study Area

Dhulikhel, situated 30 km southeast of Kathmandu is well known for both touristic destination and commercial point. It lies at 1550 m above sea level and has a warm and temperate climate with average annual temperature and rainfall being 16.7 °C and 1711 mm, respectively (Climate-Data, 2018). Between the years 2001 and 2011 the population growth rate was calculated to be 4.57% per year.

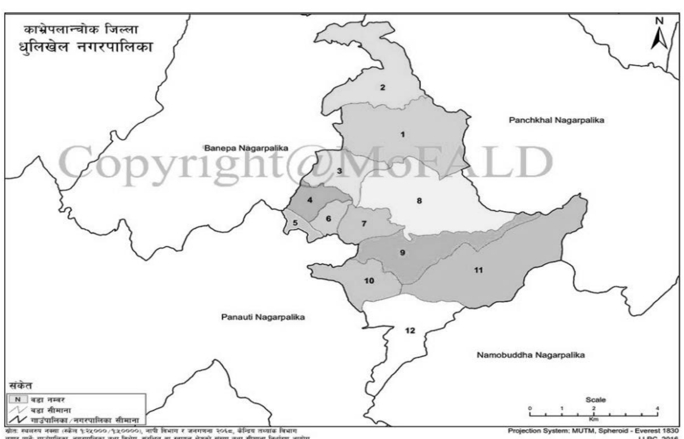

Figure1: Dhulikhel Municipality

Source of Data

Interviews with concerned authorities of Dhulikhel Municipality and Kathmandu University were done to obtain primary information for research. Primary data such as pH, EC, TS concentration, BOD, K and P were measured from the site and laboratory analysis. Secondary data needed such as statistical data, literature related to the study were obtained from various journals, articles, books and unpublished literature.

Sample Collection

The FS for the characterisation was collected from a septic tank in Kathmandu University (KU) used by approximately 64 people. The septic tank was in operation since 2015 and has not been desludged till date. A composite sample was collected by mixing the same volume of lower, middle and top layer of FS of a septic tank every week starting from August 7, 2019. A total of six samples were collected by the end whose parameters such as Total Solid (TS) concentration, Biological Oxygen Demand (BOD), Potassium (K), Phosphorus (P) and Ammonia were analysed in laboratory while pH and Electrical Conductivity (EC) were measured on the spot using the HANNA instruments, HI 98193.

Laboratory Analysis

For the analysis of some physical and chemical parameters from the study area, various laboratory experiments were conducted using standard protocols in the Kathmandu University Water Pollution Lab. The samples were also taken to the Aquatic Ecology Centre (AEC) of Kathmandu University to characterise parameters namely TKN and Potassium.

For the design of treatment units, various reference books and design manuals have been consulted. They are Faecal Sludge Management-System approach for Implementation and Operation (Strande et al., 2014), University of KwaZulu-Natal's Design manual of an ABR, 2006 (Foxon& Buckley, 2006), UNEP's Manual for Design, Construction, Operation and Maintenance of sand and gravel filter (Huhn, 2015).

RESULT AND DISCUSSIONS

Current Situation

In Dhulikhel municipality, 95% of households within ward 5 are serviced with pipe drainage systemswhile the majority of households in the other wards are serviced by septic tanks with soak pits (IUDP, 2019). This signifies the majority of population i.e. more than 80% of households in the municipality are dependent on onsite sanitation service.

According to a report by (ENPHO, 2020), in Dhulikhel municipality, 51% of the FS and WW is being safely managed either through onsite or offsite sanitation service while the other remaining 49% is unsafely managed. It is observed that a total of 22% that accounts to 13% and 9% from FS contained and FS not contained respectively is delivered to treatment. There is availability of a desludging vehicle of capacity 4000 L for removing septage from the septic tanks by the municipality. Usually, the vehicle empties 2 septic tanks per week. The rest of the FS and WW seems to be untreated and are mostly disposed of in a landfill site without treatment.

FS Characterisation

The characteristics obtained from untreated FS of KU's septic tank are tabulated in Table 1. The mean pH value and corresponding standard deviation was found to be 7.6 and ± 0.24. This is comparable to assertion made by (Heinss et al., 1999; Al-Sa'ed&Hithnawi, 2006; Cofie et al., 2006; Schoebitz et al., 2014) that

pH of faecal sludge is normally between range of 6.5 to 8.0. pH of FS is usually in neutral range due to production of methane. The mean value of EC, being the parameter used as a surrogate measure of TDS concentration was found to be 1849 ± 137 µS/cm which was realised to be low in comparison to 10977 µS/cm from the study of (Ahmed et al., 2019).FS is noted for very high total solid concentration which typically consists of suspended and dissolved solids. The mean value of the total solid concentration was 35,506 ± 17,450 mg/L and this is not different from the range of values indicated in literature (Cofie et al., 2006; Schoebitz et al., 2014). TS concentration was in slightly greater than low strength septic tank (Heinss et al., 1998; Koné& Strauss, 2004). This may be due to the use of the same septic tank by a large number of people. TVS/TS average ratio was found to be 54% which shows partial stabilization is occurring inside the tank but still a large amount of organic pollutants is to be removed before safe disposal. The high proportion of TSS (79% of TS) indicates significant volume can be reduced by settling tanks. The average value of BOD was 674 mg/L which is very low compared to other studies done by (Koné& Strauss, 2004; Cofie et al., 2006; Bassan et al., 2013; Ahmed et al., 2019). This shows the organic compound of septic tank in KU is more stabilized due to the long desludging interval which is more than 4-5 years. The mean value of NH_3-N was found to be 157.72 ± 72 mg/L that is less than 520 ± 450 mg/L and 1950 mg/L obtained from (Cofie et al., 2006; Ahmed et al., 2019) respectively but still needs to be treated before disposing or reusing. The mean values of Total Phosphorus, Potassium and Total Kjeldahl Nitrogen were found to be 24.21 ± 11 mg/L, 178.26 mg/L and 105 mg/L respectively. These concentrations of P, K and N shows that upon proper treatment, reuse of biosolids can be used as fertiliser.

Coefficients of variance for TS, TSS, TVS, BOD, TP and NH_3-N were less than 1 which showed low variation in the results obtained from the mean result obtained.

Table 1: Table showing FS characteristics

Parameter	*Unit*	*Standard deviation (±)*	*Result*
pH	-	0.24	7.6
EC	µS/cm	137	1,849
TS	mg/L	17,450	35,506
TSS	mg/L	13,806	28,214
TVS	mg/L	7,184	15,296
BOD	mg/L	200	674
NH_3-N	mg/L	72	157
TVS/TSS	-	-	0.54
SVI	mL/g	-	17.72
TP	mg/L	11	24.21
TK	mg/L	-	178.26
TKN	mg/L	-	105

Design of Faecal Sludge Treatment Plant

Depending upon effectiveness, available technologies, economic feasibility, durability, local regulations and context, a proper design of FSTP should be chosen.

In developing countries like Nepal, to prevent haphazard disposal and pollution of water bodies as well as to minimize total management cost, decentralized or semi-centralized FS treatment units are more appropriate. As shown in Figure 2, combination of Screener, Settling/Thickening tank, Anaerobic Baffled Reactor (ABR), Planted Drying Bed (PDB) and Planted Gravel Filter (PGF) are being used to design FSTP in Dhulikhel. ABR, PDB, PGF are already proven techniques and are being operated in Lubhu and Gulariya for treatment of FS.

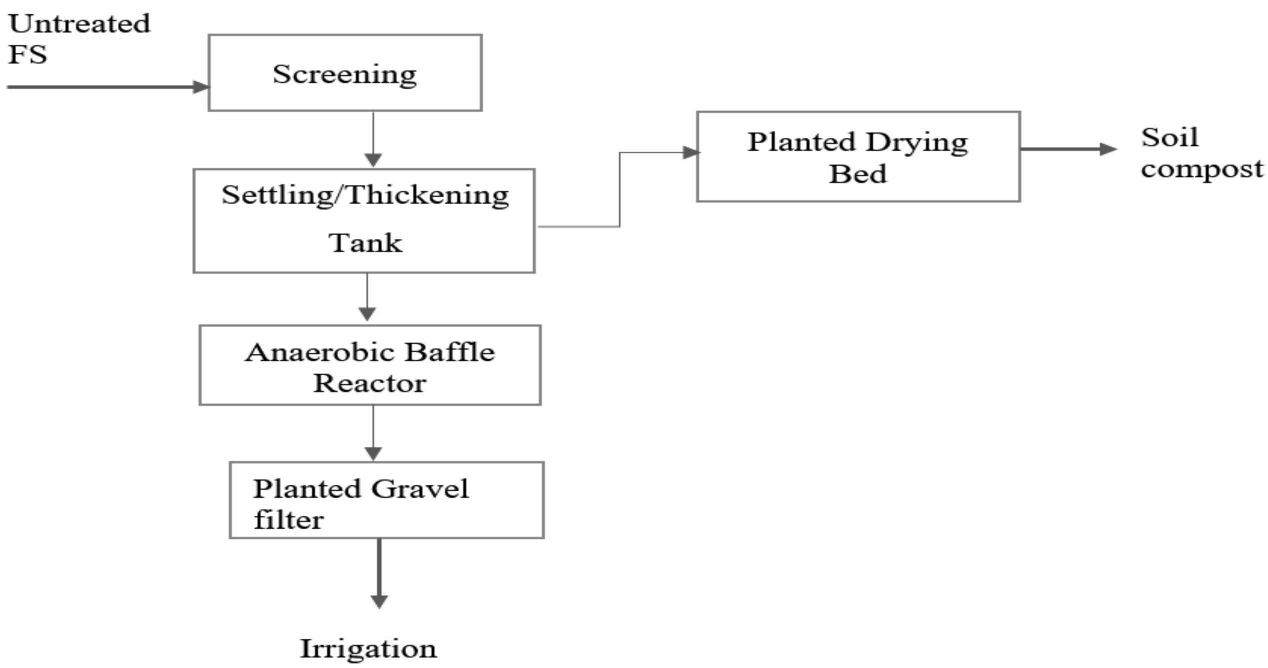

Figure 2: Design of FSTP in Dhulikhel Municipality

Design Parameter

Design period and FS volume

Growth rate of Dhulikhel is 4.57% and the base year is 2020 AD. Taking a design period of 15 years, the population is projected to be 42772 in 2035 AD. Since, per capita faecal sludge accumulation is 40 L/year (WHO, 1992), total sludge accumulated in Dhulikhel is estimated to be 1,710 m^3/year.

Opening Time

FSTP is designed to operate 260 days/year, 5 days/week and 7 h/day.

So, volume of faecal sludge to be collected per day by the vacuum truck = 1710/260

= 6.5 m^3 /day

Since, 26% of total FS generated is being treated (ENPHO, 2020), so

volume of faecal sludge to be collected per day by the vacuum truck = 4.81 m^3 /day

However, the design discharge of 6 m^3/day (Assume, peak factor = 1.2) has been considered for the design. This is equivalent to around 2 trips of FS per day if truck volume is 3 m^3.

TS and TSS concentration

For our design, we have considered 35.51 g/L and 28.21 g/L of TS and TSS concentration, respectively obtained from characterisation of FS sample.

Components of FSTP

Settling/Thickening tank

Settling-thickening tanks are efficient as a treatment step after screening as they rapidly achieve solids-liquid separation. They have efficiency of 60-80% of SS in settled volume.

Two thickening tanks with each of length 9 m, width 1.5 m and depth 2.05 m are proposed; each week one tank will be used for loading FS while in other tank about 8.5 m^3 thickened sludge will be extracted per week and transferred to PDB and around 4.3 m^3 supernatant liquid will be drained to ABR per day. The concentration of SS found in FS of Dhulikhel is higher, so concentration of 80 g TSS/L is achievable in 9.225 HRT of thickening.

Planted Drying Bed

6 PDB each with length and breadth of 11 m and 4 m respectively are proposed. 200 kg TS/m^2/year will be loaded to each PDB and *PhragmitesKarka*will be used in our PDB as this species of plant has already been successfully in operation in the Reed Bed Treatment Plant within KU. A 10 cm layer of sand at top, 15 cm layer of medium gravel at middle and 45 cm of large gravel at bottom will be used to create a filter matrix in each PDB unit. Removal efficiencies of TS from sludge is about 66 to 88% which can be taken from the example of Thailand and Ghana treatment system. The eachate of each PDB will be sent to ABR for further treatment and biosolids rich in N, P, K can be later used as fertiliser.

Anaerobic Baffled Reactor

The design of ABR is based on flow of 4.3 m^3/day of WW drained from the settling tank, working volume 9 m^3 (2.75 m * 2.2 m * 1.5 m) with 5 compartments and HRT 48 hours is proposed. Usually, the treatment efficiency of 65-90% can be achieved for COD, 70-95% for BOD and for further treatment of WW (BORDA, 2009), it gets transferred to PGF.

Planted Gravel filter

The effluent from ABR is passed through PGF where the pollutants present in the WW are degraded aerobically flowing horizontally across vertical gravel and stone layers. The effluent water obtained from PGF can be used for irrigation or stored for any other purpose. In this design, *PhragmitesKarka*will be planted in a Gravel filter to support aeration and avoid clogging. The filter media is covered by a 5 cm layer of the coarse gravel. The inlet and outlet pipes will have slope of 2%, which equals to 2 cm decline per one meter of pipe to adapt filter to individual step up. Filter area of 2 m^2 per 100 litre is required, so our total filter area is 86 m^2.

CONCLUSION

This study provides an insight into the status of FS and its management within the Dhulikhel municipality. It reveals that there is an immediate requirement of proper treatment in Dhulikhel municipality as almost 50% of the FS and WW are still unmanaged.

The characterisation result shows that the concentrations of TS, TKN, NH_3-N and BOD were very high compared to typical WW causing environmental and health concern. It was also found that the samples collected had high concentrations of Potassium, Phosphorous and Nitrogen showing positive results to be reused as soil conditioner and fertilizer. Moreover, the FS characterisation studies are essential to quantify the data prior to designing of the FSTP.

Further studies are required to determine the characteristics of FS and ultimately, achieve sustained performance through proper designing of the FSTP. Therefore, it is recommended that proper optimization for design be evaluated.

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REFERENCES

1. Ahmed, I., Ofori-Amanfo, D., Awuah, E., & Cobbold, F. (2019). A Comprehensive Study on the Physicochemical Characteristics of Faecal Sludge in Greater Accra Region and Analysis of Its Potential Use as Feedstock for Green Energy. *Journal of Renewable Energy*, *2019*, 1–11. https://doi.org/10.1155/2019/8696058
2. Al-Sa'ed, R., & Hithnawi, T. (2006). Domestic septage characteristics and co-treatment impacts on Albireh wastewater treatment plant efficiency. *Dirasat: Engineering Sciences*, *33*(2), 187–198.
3. Bassan, M., Tchonda, T., Yiougo, L., Zoellig, H., Mahamane, I., Mbéguéré, M., & Strande, L. (2013). Characterization of faecal sludge during dry and rainy seasons in Ouagadougou, Burkina Faso. *36th WEDC International Conference: Delivering Water, Sanitation and Hygiene Services in an Uncertain Environment*, (September 2011), 1–7.
4. BORDA (2009*):* EmSan - Emergency Sanitation. An innovative & rapidly installable solution to improve hygiene and health in emergency situations. Bremen: Bremen Overseas Research and Development Association.
5. CBS. (2011).Central Bureau of Statisticshttps://cbs.gov.np/(accessed 19 June 2019)
6. Climate-Data.org. (2018). Average Temperature, weather by month, weather averages (Upington). Climate-Data.org website: https://en.climate-data.org/africa/ethiopia/amhara/kuta-ber-55524/%0Ahttps://en.climate-data.org/europe/spain/catalonia/barcelona-1564/(accessed 4February 2020)
7. Cofie, O. O., Agbottah, S., Strauss, M., Esseku, H., Montangero, A., Awuah, E., & Kone, D. (2006). Solid-liquid separation of faecal sludge using drying beds in Ghana: Implications for nutrient recycling in urban agriculture. *Water Research*, *40*(1), 75–82. https://doi.org/10.1016/j.watres.2005.10.023
8. ENPHO (2020). *SFD Promotion Initiative Dhulikhel Nepal Final Report*. https://www.susana.org/_resources/documents/default/3-4078-7-1615371298.pdf(accessed 12 March 2022)
9. Foxon, K., & Buckley, C. (2006). Guidelines for the Implementation of Anaerobic Baffled Reactors for on-Site or Decentralised Sanitation. *Proceedings: WISA Conference*, (1), 1–12.
10. GOEC-GIDA-NEXT JV. (2019). *Government of Nepal Dhulikhel Municipality Integrated urban development plan of Dhulikhel Municipality Volume 2 : Physical Development Plan GOEC-GIDA-Next JV*. *2*.
11. Heinss, U., Larmie, S. A., & Strauss, M. (1998). *Solids Separation and Pond Systems Treatment of Faecal Sludges In the Tropics*. (05).
12. Heinss, U., Larmie, S. a, & Strauss, M. (1999). Characteristics of Faecal Sludges and their Solids-Liquid Separation. SOS- Management of Sludges From On-site Sanitation. EAWAG/SANDEC. *SOS - Management of Sludges from On-Site Sanitation*, (January), 10.
13. Huhn, L. (2015). *Manual for Design, Construction, Operation and Maintenance of sand and gravel filter*.
14. Koné, D., & Strauss, M. (2004). *Low-cost Options for Treating Faecal Sludges (FS) in Developing Countries – Challenges and Performance*.

15. Niwagaba, C. B., Mbéguéré, M., & Strande, L. (2014). Faecal Sludge Quantification, Characterisation and Treatment Objectives. In *Igarss 2014*. https://doi.org/10.1007/s13398-014-0173-7.2

16. R Franceys, J., Pickford, J., & Reed, R. (1992). *A Guide to the Development of on-Site Sanitation*. http://www.who.int/water_sanitation_health/hygiene/envsan/onsitesan.pdf(accessed 15 June 2019)

17. Schoebitz, L., Bischoff, F., Ddiba, D., Okello, F., Nakazibwe, R., Niwagaba, C., … Strande, L. (2014). *Results of faecal sludge analyses in Kampala, Uganda*. Retrieved from http://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/Laboratory_Methods/results_analyses_kampala.pdf

18. Strande, L., Niwagaba, C. B., &Mbeguere, M. (2014). *Faecal Sludge Management Systems Approach for Implementation and Operation*.

19. Strande, L., Schoebitz, L., Bischoff, F., Ddiba, D., Okello, F., Englund, M., Niwagaba, C. B. (2018). Methods to reliably estimate faecal sludge quantities and qualities for the design of treatment technologies and management solutions. *Journal of Environmental Management*, *223*, 898–907. https://doi.org/10.1016/j.jenvman.2018.06.100

20. UNICEF, & WHO. (2015). *2015 Update and MDG Assessment*.

MODELING AND SIMULATION OF GUHESWORI WASTEWATER TREATMENT PLANT USING STOAT

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ABSTRACT

The study adopts the International Water Association's Activated Sludge Model Number 1 (ASM1) in STOAT for the dynamic simulation of an activated sludge-based treatment plant at Guheswori, Kathmandu. Wastewater Treatment Plants (WWTPs) often experience unexpected changes in flows and pollutant loads, sometimes due to illegal dumping of fecal sludge in the sewer networks. This study was performed to evaluate the performance of the upgraded unit of the Guheshwori WWTP treatment plant under actual and varying pollutant loads. The primary model was constructed using 14 days' performance and dimensional data of Guheswori WWTP and was validated against the effluent limits provided to the treatment plant. The scenario analysis was performed by increasing influent flow by 100 m^3/h and 22,000 kg BOD at every 10.00 p.m. of alternate days to simulate the addition of fecal sludge during the low flow period at night. The results for the normal operating conditions were within the threshold, which proved the reliability of the software for modeling WWTPs. The simulated effluent parameters after theaddition of fecal sludge to the treatment plant were extremely high and not acceptable to effluent discharge requirements suggesting a careful feeding strategy. The model can be used to estimate the response of the system to a diversity of problems in each process and operational control and assist in the planning of future upgrades of the plant to incorporate the co-treatment of high-strengthed side-streams.

KEYWORDS

Activated sludge process, ASM1 model,Wastewater modeling, Wastewater treatment plant

INTRODUCTION

The growing demand for wastewater treatment calls for new approaches for wastewater collection and management. A sustainable and effective wastewater management plan foremost includes sound knowledge on every aspect of wastewater treatment technology. For this, wastewater process models have been developed and applied. Wastewater process models are the essential tools for understanding relevant aspects of wastewater treatment plants. They provide options for upgrades and a better understanding of new plant design, as well as improvements of operational controls of the existing ones. The process models can be used to evaluate and optimize plant performance and plan future upgrades of the plant. There are severaluser-friendly software packages available such as BioWin®, GPS-X®, STOAT®, Aquadesigner and others which solve a series of simulated equations simultaneously to propose several solutions to a specific facility (Mohamadi et al., 2015). In this study, Sewage Treatment Analysis Over Time (STOAT) software has been used to evaluate the performance of the hydraulics of the existing GWWTP at Kathmandu. The built model can further be used to estimate the response of the system to the diversity of problems in each unit's processes and operational controls and assist in the planning of future upgrades of the plant.

Guheswori Wastewater Treatment Plant (GWWTP) was commissioned in 2001 A.D with the original design of 74,000 equivalent persons (4430 kg BOD_5/day, 60 g inh/day) (KUKL, 2018).The plant became considerably overloaded due to population growth and could not receive the total influent load to the treatment process. A subproject for the rehabilitation and expansion of the GWWTP was then introduced with several changes in technologies used in the unit processes. The WWTP enhanced its capacity from an average flow of 16.2 MLD to an average flow of 30.2 MLD with minimum structure life of 60 years.

Even after its up-gradation, the GWWTP is experiencing changes in pollutant loads than expected and a sudden increase in influent organic loads. As it is a newly upgraded treatment plant, the variation in pollutant loads can affect its performance. This existing scenario requires knowledge on the kinetics of pollutant removal and hydraulic loading rates, feasibility analysis for optimization and improved performance of the WWTP. The possibility of co-treatment of fecal sludge can be explored using model simulation. The simulated model developed for the recently upgraded GWWTP using STOAT gives a better understanding of the new plant design along with the improvements made in its operating parameters. It provides an overall assessment of the impacts of varying hydraulics and pollutants load on the treatment plant's performance. This study was performed to model and simulate the impact of varying hydraulic and pollutant loads on the performance of the new unit of GWWTP.

MATERIALS AND METHODS

Data Collection

Both primary and secondary data were used for simulation. User-defined model parameters were collected from primary sources whereas secondary data collection was done to have insights on default model parameters and choice of model for running the simulation. The primary sources include data from field observations, key informants and laboratory analysis data. The dimensional and performance figures of each unit processes shared by the concerned authorities of GWWTP were used for simulation which included i) Average flow, Peak flow, Temperature, Biological Oxygen Demand (BOD), pH, Total Kjeldahl Nitrogen (TKN), Dissolved Oxygen (DO), Total Suspended Solids (TSS) of Influent, ii) Bar Spacing of Screening, iii) Average Grit Production, Volume, Length, Width and Depth of the Grit Chamber, iv) Number of compartments, Total BOD, Volume, Liquid Depth and Surface Area of Primary Sedimentation Tank, v) Number of Stages, RAS flow, Sludge Volume Index (SVI), Wastage Flow, Mixed Liquor Suspended Solids (MLSS) Concentration and DO in Activated Sludge of Activated Sludge Aeration Tank, vi) Number of compartments, Surface Area, Volume, Effective Depth of Tank, BOD and TSS of Secondary Sedimentation Tank.

The secondary source of data includes the 14-day average performance data along with the physical dimensions of unit processes from PID, KUKL. The model parameters not available on the performance data of GWWTP were determined through laboratory analysis which included i) Total Solids, Total Suspended Solids,Total BOD and Soluble BOD of influent, ii) Total BOD and Soluble BOD of Primary Sedimentation tank effluent, and iii) Total BOD and Soluble BOD of Secondary Sedimentation Tank effluent.

Modelling Activated Sludge Process in STOAT

Figure 1 shows the working model of GWWTP prepared on STOAT. The influent wastewater is passed through screening and grit removal unit to the primary settling tanks, which connects to activated sludge aeration tank and secondary settler for settlement undergoes disc filtration (not shown in Figure 1) and disinfection in the chlorination tank and finally discharged through the effluent stream. The secondary sedimentation tank returns to the activated sludge aeration tank to pump back the returned sludge. The model comprises a single-stage activated sludge aeration tank and four vertical layers in the secondary sedimentation tank.

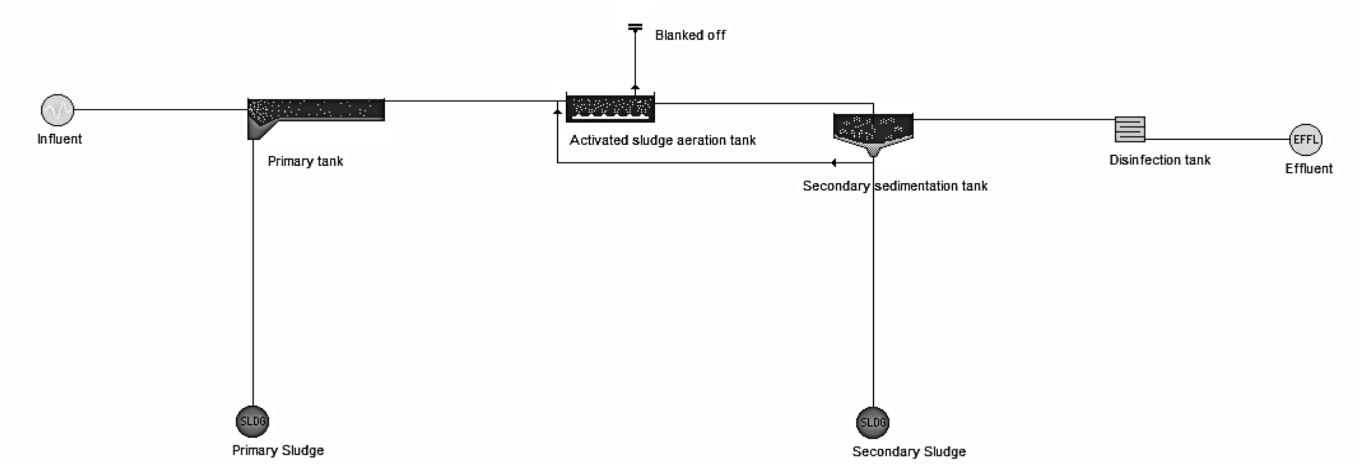

Figure 1: General Layout of GWWTP in STOAT

The following section illustrates the models employed for the simulation of GWWTP in STOAT.

Primary Tank BOD Model

The model assumes that the ratio between settleable and non-settleable fraction in the incoming sewage for each component as fixed. Particulate BOD, volatile and non-volatile solids are divided into settleable and non-settleable fractions. The sludge is assumed to be removed continuously, so there is no allowance for sludge build-up within the primary tank (Gochis et al., 2015).

ASM1 Model

The Activated Sludge Process (ASP) is composed of two main units; a biological reactor and a settler. ASM1 model is employed as a bioreactor model. ASM1 was primarily developed to describe the removal of organic compounds and nitrogen with simultaneous consumption of oxygen and nitrate as electron acceptors. The model is considered a reference model since this model triggered the general acceptance of biological process modeling.

Model Selection

BOD model was chosen in the primary tank according to the influent data form presented in Table 1. ASM1 model was chosen to simulate the process in the activated sludge aeration tank. The model incorporates

oxidation and simultaneous nitrification and denitrification process. The model makes a simplifying assumption that the particulate BOD is hydrolyzed rapidly and denitrification is only permitted when the DO is zero. SSED1 model was selected as a secondary settler tank model according to the match of models in aeration and settling tank. SSED1 model uses corresponds to the associated activated sludge model ASM1 model in the activated sludge aeration tank.

Model Running and Simulation

The model runs at a dynamic simulation of 15 days on a flow rate of 312.5 m^3/h with phase 20, implying the peak flow occurs everyday at 10:00 am. The user-defined influent parameters of wastewater are presented in Table 1. The primary tank includes 4 compartments with a total volume of 1680 m^3. The activated sludge aeration tank operates on 2 compartments with an SVI of 105 and a total volume of 5400 m^3. The secondary settling tank runs on 4 chambers with a sludge wastage flow of 43.7 m^3/h and RAS flow of 380.75 m^3/h, the total volume of the unit being 3000 m^3. The wastage method in SST was specified as constant to operate the model with specified wastage flowrate and pumping cycle. The K_{La} values were maintained between 2 and 10 to control the DO concentration of 2 mg/lin the aeration unit which was the user-entered setpointof DO in the unit.

Table 1:Initial conditions of influent profile

Model Parameters	**Input**
Average Flow	312.5 m^3/h
Temperature	18°C
pH	7.1
Soluble BOD	45 mg/l
Particulate BOD	265 mg/l
Volatile Solids	567.75 mg/l
Non-Volatile Solids	189.25 mg/l
Dissolved Oxygen	1.8 mg/l
Total Dissolved Solids	437 mg/l

Simulation Undervarying Flow and Load Conditions

The two scenario analyses were performed to assess the treatment plant's performance under varying load and flow conditions. For the first scenario analysis, the influent flow was increased by 100 m^3/h and for the second scenario analysis, the influent BOD load was increased by a typical fecal sludge concentration of 22,000 kg BOD (Heinss et al., 1999) assuming feedingof 30 m^3fecal sludge to the inlet of the treatment plant at10.00 pm in every alternate day during the 15 days dynamic simulation. The scenario analysis was done at 10:00 pm on alternate days as the flow is low during the nighttime.

Plant Wide Model of GWWTP

The influent wastewater is passed through screening and grit trap to a primary settling tank, which connects to activated sludge aeration tank and secondary settler for settlement undergoes disinfection in the chlorination tank and then is discharged through the effluent stream. One part of the secondary sedimentation tank returns to the activated sludge aeration tank to pump back the returned sludge. The system comprises a single-stage activated sludge aeration tank and four vertical layers in the secondary sedimentation tank.

The effluent results were divided into two groups for evaluation. The first group includes effluent BOD and the second group includes effluent suspended solids. The closeness rates for simulation results with

GWWTP's effluent limits for total BOD and total suspended solids were then compared. The effluent total BOD includes soluble BOD and particulate BOD. The performance efficiencies of the model for the removal of total BOD and TSS were calculated.

RESULTS AND DISCUSSION

Results of Plant-Wide Simulation

This study simulated the performance of GWWTP at actual and varying pollutant flow conditions. The effluent simulation results under the normal operating conditions hold a very good closeness to the actual performance of the treatment plant.The comparison between the model output and influent wastewater along with GWWTP's effluent limits for total BOD and TSS is presented in Table 2.The total predicted BOD and TSS by the model is within the effluent limits of GTTWP. The mean effluent total solids and total BOD obtained from simulation were 4.89 mg/l and 2.89 mg/l with the maximum value of the parameters being 7.33 mg/l. and 6.36 mg/l, respectively. The total solids mass was obtained as 524.02 mg/l and total BOD mass was obtained as 293.27 mg/l. The model outputs show performance efficiency of 99.06% and 99.35% for the removal of total BOD and TSS which portray a high closeness rate to the actual performance efficiency of the treatment plant. The mean effluent soluble BOD and particulate BOD were observed as 1.08 mg/l and 1.89 mg/l, respectively. The standard deviations of soluble BOD and particulate BOD from the model were observed as 0.54 and 0.56, respectively. The soluble BOD mass was 99.369 kg and that of particulate BOD was 193.905 kg. The peak loadvalueswere 0.454 g/s and 0.333 g/s forsoluble and particulate BOD, respectively.

Table2: Comparison of model results for total BOD and TSS within fluent wastewater

Parameters	Influent WW Concentration (mg/l)	Model Output (mg/l)	Effluent Limits*(mg/l)	Performance Efficiency
Total BOD_5	310	2.89	<10	99.06
Total Suspended Solids	437	4.89	<10	99.35

*Limits of effluent discharge for GWWTP

Simulation of Primary Sedimentation Tank

Table 3 shows the reduction of total BOD_5 from 310 mg/l in the influent stream to as low as 226.1 mg/l in the primary settling tank. This portrays a 27 % reduction of total BOD in PST. The settleable particulate BOD reduced from 159 mg/l to 62.3 mg/l and the non-settleable particulate BOD increased from 106 mg/l to 115 mg/l. The results of total BOD were obtained as soluble BOD, settleable particulate BOD and non-settleable particulate BOD as shown in Figure 2. The soluble BOD increased from 0 to 42.8 mg/l at elapsed hour 1:00. The highest value was observed at elapsed hours 12:00 and 13:00 as 61.4 mg/l. The lowest value was achieved at elapsed hour 26:00 (2 am of Day 2) as 37.5 mg/l. The recurring pattern showed the highest peaks every day at 13:00 hours. The mean, minimum and maximum soluble BOD were observed as 48.8 mg/l, 0 mg/l and 61.4 mg/l, respectively.

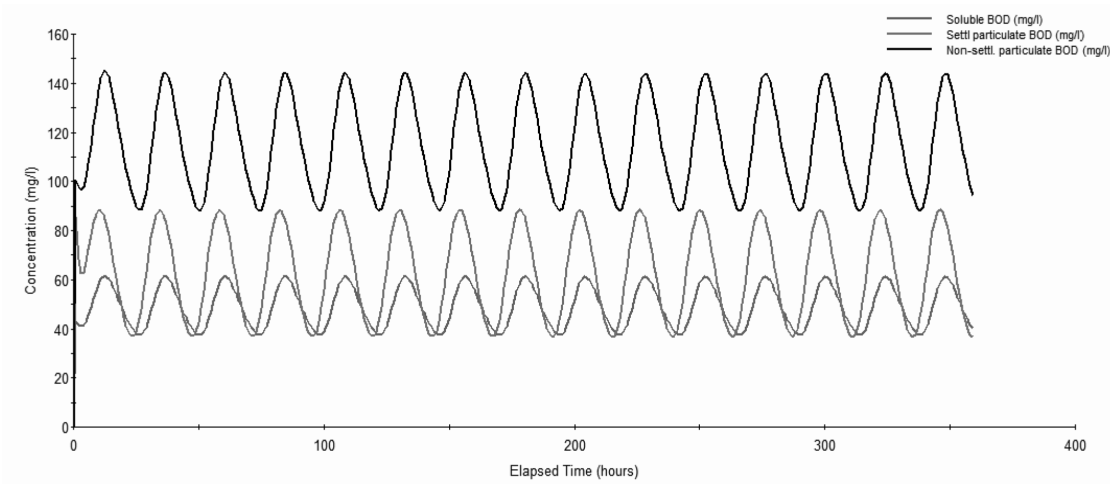

Figure 2: Simulation results of total BOD in PST

Table 3: Comparison of model results between unit processes and influent wastewater

Parameters	**Influent WW-Concentration (mg/l)**	**PST Model Output (mg/l)**	**AerationTank Model Output(mg/l)**	**SST Model Output (mg/l)**	**Effluent Model Output (mg/l)**
Total BOD	310	226.1	4.6	-	2.89
Soluble BOD	45	48.8	0.8	Stage1: 1.1 Stage2: 1 Stage3: 1 Stage4: 0.8	1.08
Particulate BOD	265	117.3	3.8	-	1.81
Settleable Particulate BOD	159	62.3	-	-	-
Non-Settleable Particulate BOD	106	115	-	-	-
Settleable Volatile Solids	340.65	166.4	-	-	-
Non-Settleable Volatile Solids	227.1	155.1	-	-	-
Settleable Non-Volatile Solids	113.55	55.5	-	-	-
Non-Settleable non-Volatile Solids	75.7	51.7	-	-	-
TSS	437	-	-	-	4.89

Results of Activated Sludge Aeration Tank

The simulation results of the activated sludge aeration tank effluent are shown in Figure 3. The model output showed a reduction of total BOD from 226. 1mg/l in the PST outlet to as low as 4.6 mg/l in the activated sludge aeration tank (Table 3). This port rays a 97.9% reduction of total BOD in the aeration unit. shows the curve of total BOD in the aeration unit.

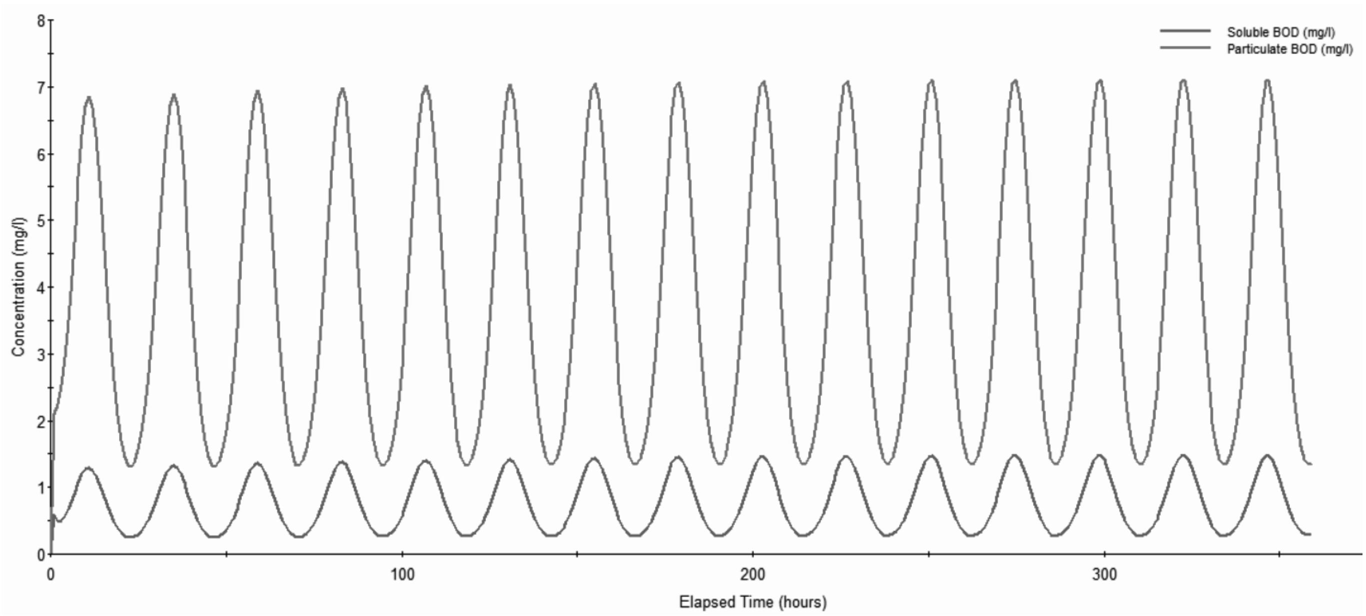

Figure 3: Simulated result of total BOD in Activated Sludge Aeration Tank

Results of Secondary Sedimentation Tank

The model output (Figure 4) shows no remarkable difference in the soluble BOD content of the aeration tank and SST. The mean soluble BOD at the final stage of SST from the model output was 0.8 mg/l which equals that of soluble BOD effluent of the aeration tank. The mean soluble BOD in stage 1,2,3 and 4 was observed as 1.1 mg/l, 1 mg/l, 1 mg/l and 0.8 mg/l respectively. The minimum value of mean BOD was 0 mg/l in all the stages. The maximum value of soluble BOD was observed as 4.4, 4.9, 6.2 and 12.6 mg/l in stages 1,2,3 and 4, respectively.

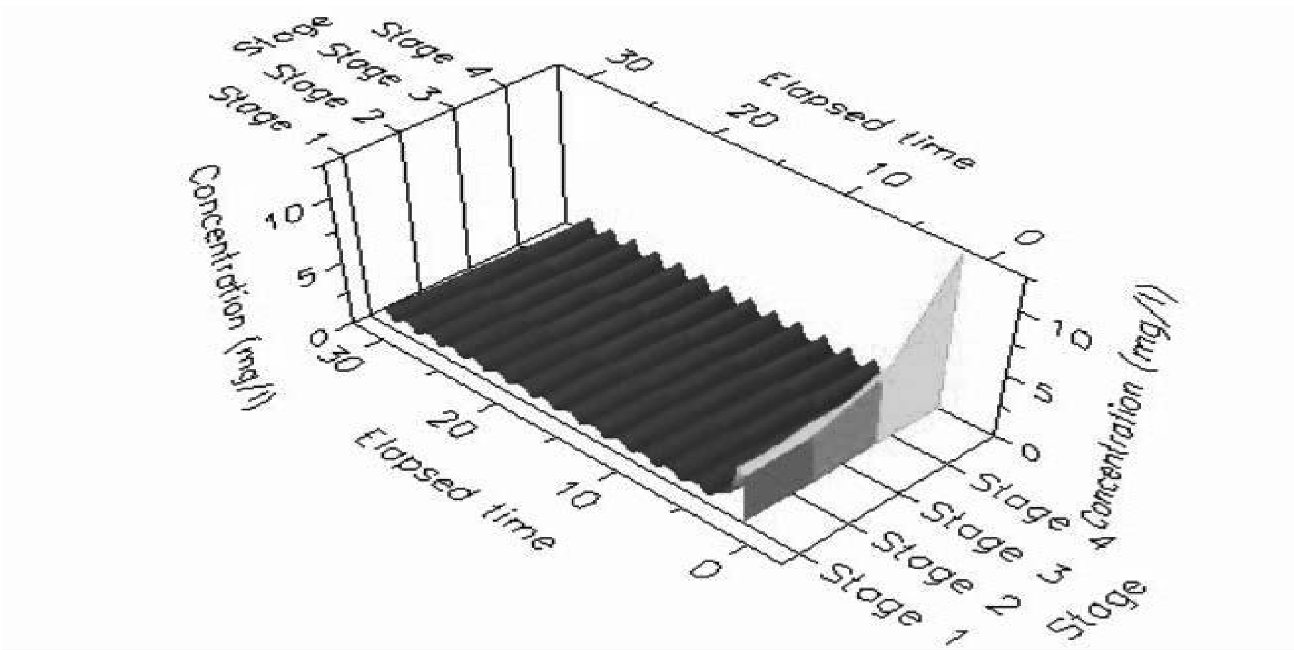

Figure 4: Results of Soluble BOD in Secondary Sedimentation Tank

The model output of non-settleable solids indicates an overall good settlement of solids in the unit. It could be seen that the mean non-settleable solids are as low as 1.5 mg/l in relatively all four stages. The simulation output shows a recurring pattern and fairly constant figures with increasing time. The mean non-settleable solids were observed as 1.5 mg/l, 1.5 mg/l, 1.5 mg/l and 1.6 mg/l in stages 1, 2, 3 and 4 respectively. The minimum value was 0 and the maximum value was 1.7 mg/l in all the stages.

The conventional wastewater quality parameters in the treated effluent lie within the Nepal government standard for effluent discharge of combined industrial effluent treatment plants. The performance removal efficiency of total BOD and total solids were also found to be 99.06 % and 99.35 %, respectively. It can be concluded that the treatment system and operating conditions of GWWTP is quite efficient to maintain the effluent parameters of total BOD and total solids.

Results of Chlorination Tank

The model predicted maximum removal of E. coli as 99.9% with 1% hypochlorite solution used as a disinfectant with a contact time of 15 minutes. The simulation results of the chlorination tank showed the mean % removal of E. coli as 92.8 with the minimum % removal being 83.2. The results however have not been calibrated or validated with the actual performance data.

Scenario Analysis Under Increased Flow and BOD_5 Load

The scenario analysis was done to see the effect of increased flow and BOD_5 load on effluent BOD and suspended solids. The comparison between the model output and influent wastewater along with GWWTP's effluent limits for total BOD and TSS is presented in Table 4. The closeness rates for simulation results with GWWTP's effluent limits for total BOD and total suspended solids were compared.The mean total BOD and mean total solids were observed to be 7.56 mg/l and 15.32 mg/l, respectively, with the maximum total BOD and total solids being 34.57 mg/l and 20.7 mg/l. This means though the treatment plant performs well, it exceeds the tolerance limits for TSS before its disposal to the environment under the provided circumstance. The percentage removal efficiency of total BOD and TSS were calculated only as 97.56% and 96.45%, respectively, indicating good settlement of solids.

The results show that the model output under increased BOD load highly exceeds the effluent limits for GWWTP. The mean total BOD and mean total solids were observed to be 71.38 mg/l and 162.12 mg/l respectively, with maximum total BOD and total solids being 206.68 and 486.49 mg/l respectively. This means the treatment plant cannot perform well and exceeds the tolerance limits prior to its disposal to the environment under the provided circumstances The percentage removal efficiency of total BOD and TSS were calculated only as 76.97 % and 61.98 % respectively, indicating poor settlement of solids. This shows the addition of fecal sludge of treatment plant to handle the sudden increase in influent flow and BOD load.

Table4: Comparison of model results of the scenario for increased flow and BOD_5 load for total BOD_5 a nd TSS with effluent limits

Parameters	Influent WW concentration (mg/l)	Effluent limits(mg/l)	Model Output for the increased load (mg/l)	Model Output for increased BOD_5(mg/l)
Total BOD	310	<9	7.56	71.38
TSS	437	<8	15.32	162.12

CONCLUSION

This study simulated the performance of GWWTP at actual and varying pollutant flow conditions. The effluent simulation results under the normal operating conditions hold a very good closeness to the actual performance of the treatment plant. The GWWTP has actual total effluent BOD and total solids less than 9 mg/l and 8 mg/l, respectively. The simulation results show final effluent total BOD and total solids as 2.89 mg/l and 4.89 mg/l, respectively which lies within the effluent threshold at which the treatment plant

operates and validates the model. The scenario analysis for the sudden increase in flow showed the difficulty in meeting the TSS limits(BOD - 7.56 mg/l and TSS - 15.32 mg/l). The scenario analysis for increased BOD load due to additional of fecal sludge showed noticeable fluctuations in the overall settlement of solids and total BOD removal (BOD- 71.38 mg/l and TSS- 162.12 mg/l) which exceed the effluent threshold limits provided to the treatment plant as well as the government guidelines. Though the co-treatment of fecal sludge is possible, a careful feeding strategy must be designed to maintain the effluent discharge limits. Overall, the models in STOAT can be used to improve the effluent quality, reducing the risks of consent failures. The software also reduces capital and operational costs for the performance evaluation of WWTP.

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REFERENCES

1. *Mohamadi, F., Rahimi, S., Bina, B., & Amin, M. (2015). Modeling of Activated Sludge withASM1 Model, Case Study on Wastewater Treatment Plant of South of Isfahan. CurrentWorld Environment, 10(Special-Issue1), 96–105.*
2. Gochis, D. J., Yu, W., & Yates, D. N. (2015). *The NCAR WRF-Hydro Technical Description andUser's Guide, version 3.0. NCAR Technical Document*. *May*, 120.http://www.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf%0Ahttp://www.mmm.ucar.edu/wrf/users/.%0Ahttp://www.ral.ucar.edu/projects/wrf_hydro/.(accessed 20 September 2020)
3. Heinss, U., Larmie, S. a, & Strauss, M. (1999). Characteristics of FaecalSludges and theirSolids-LiquidSeparation.SOS-ManagementofSludgesfromOn-SiteSanitation.http://www.sswm.info/sites/default/files/reference_attachments/HEINSS et al 1994Characteristicsof FaecalSludges and theirSolids-Liquid Seperation.pdf(accessed 22 September 2020)
4. Wang,W.,Shi,C., Yang,J.,Zeng, M.,Dai,Z., &Zhang,Z. (2019).Modellingperformanceofoxidation ditch in wastewater treatment plant by STOAT software. *IOP Conference Series:Earth and Environmental Science*, *300*(3), 0–5.

EVALUATION OF RUNOFF REDUCTION AFTER THE DEPLOYMENT OF LID THROUGH SWMM: A CASE STUDY IN SURYABINAYAK MUNICIPALITY IN NEPAL

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ABSTRACT

Increased imperviousness resulting from rapid and unplanned urbanization can cause undesirable effects such as flooding during storm events, and increased pollutant discharge to receiving waters. This problem is exacerbated in cities in Nepal where the performance of sewer networks is marred by improper design, illegal lateral connections, and poor maintenance. This paper presents a case of Suryabinayak Municipality in Bagmati Province, Nepal of which the sewer network has been simulated in the US Environmental Protection Agency's (EPA)'s Storm Water Management Model (SWMM version 5.1). The flood volumes and outfall loadings were analyzed for 20 years (until 2040) for the existing drainage system and the changes in volumetric flow when three low impact development (LID) practices: i) rain barrel, ii) green roof, and iii) rain garden, respectively was included in the sewer sheds one at a time. The total average sanitary flow for over 20 years of design year period (2040) was found to be 3.3 MLD. The results showed that the existing combined sewer network (reference case) is not capable of sustaining the design flow as 38 out of 189 numbers nodes flooded in the design rainfall of 101.1 mm for 24 hours (2 years return period). When the rain barrel was included, the total runoff was 14 % less than the reference case. This reduction was higher still for green roof and rain garden, 37% and 42%, respectively, in comparison to the reference case. In the same way, the flood volume for the three LIDs scenarios reduced by 14%, 37%, and 42%, respectively. These results show that the capacity of existing sewer networks can be enhanced by the implementation of sustainable urban water management techniques like LIDs.

KEYWORDS

Urbanization; SWMM; LID; Sustainable Urban Drainage

INTRODUCTION

The rapid growth of cities (in coverage and population) in Nepal has led to a drastic increase in water consumption and wastewater generation, aggravating the risks of water scarcity, and wastewater conveyance and treatment issues (Aihara et al., 2015). This issue is further exacerbated in light of other issues: improper design, illegal lateral connections, and poor maintenance. Unplanned urbanization, as is the case in Nepal, adversely affects the hydrological cycle as the rise in impervious areas increases surface runoff at expense of other hydrological processes. Other possible impacts of such urbanization include deterioration of storm runoff water quality, increase in combined sewer overflows (CSOs) volumes and frequencies, obstruction and blockade of the stormwater drainage system, and frequent flooding of streets. Nepal has been encountering severe urban pluvial flooding resulting from improper drainage management, climate change and increased built-up areas (Pradhan-Salike & Pokharel, 2017). Thus, implementation of green and sustainable drainage management practices is a must to establish appropriate and properly managed urban drainage and mitigate the problem of urban flooding.

Low Impact Development (LID) designs aim to replicate the natural pre-development hydrological condition through total runoff volume control, peak flow rate control, flow frequency/duration control, and water quality control (USEPA, 2000). A few examples of commonly used LIDs include rain gardens, bio-retention cells, and green roofs (Rossman & Huber, 2016). LIDs could provide an effective attenuation of stormwater runoff from the expanding cities and prevent or delay its onset into the drainage system. Earlier studies have shown encouraging results, Gong et al. (2019) have demonstrated an average CSO frequency reduction of 22%, and volume reduction of 35 % to 49% through LID implementation.

There are various modeling tools to analyze the quality and quantity of stormwater and sanitary sewage. The United States Environmental Protection Agency's (EPA) Storm Water Management Model (EPA SWMM version 5.1) is a widely used program for simulating urban runoff quantity and quality (Gironás et al., 2010; Rossman, 2015). EPA SWMM 5.1 is available in the public domain and has been successfully applied across a wide range of geographical areas (Hossain et al., 2019). Studies show that flooding analyses using SWMM have helped to determine the areas with the greatest risk, and found weak points in sewer networks (Fu et al., 2011; Gersonius et al., 2013; Huong and Pathirana, 2013). SWMM also allows for LID analysis (Rossman, 2010), and has found application in various research works. A case study done in China to evaluate the runoff effect of the LID through SWMM showed that the LID measures are effective in controlling the surface runoff of the storm events with return periods shorter than five years (Luan et al., 2017).

In this study, ward number five of the Suryabinayak Municipality has been considered which has been reported for devastating incidents of urban flooding in the year 2018 on July 11 and 12 (Prajapati & Talchabhadel, 2018). Low Impact Developments techniques can serve as natural, cost-effective and sustainable techniques for runoff reduction thereby mitigating the flooding consequently. Hence, this paper aims to access the hydraulic capacity of the sewer network of Suryabinayak ward-5 and evaluate the impact and effectiveness of LIDs on receding the sewer overflows and flooding. The analysis of the sewerage system in the study area has been accomplished using secondary sources (published literature, maps, and stakeholder meetings), GIS software, and the SWMM model. The model was selected due to the dynamic rainfall-runoff properties of the model which is adequate for the simulation of water quantity and quality related to urban run-off.

MATERIALS AND METHODS

Study Area Description

Figure 1 shows the study area of our research. The study area is Suryabinayak Municipality ward no. 5 (27°40′N, 85°24′E) located in Suryabinayak, Bhaktapur in Bagmati Province, Nepal, and is divided into 10 wards. It covers an area of 2.86 sq. km. The population and the population density of the study area are 10,560 and 3,692.31/sq. km. respectively (CBS, 2011). The land is mostly covered by built-up area with 44.79%, 11.87% of barren land, 37.78 % of Agricultural/ grassland and only 5.56 % of forest area. The study site has the majority of residential areas and few commercial areas.

Figure 2 shows the overall methodological approach followed in this research study. The study began with the collection of baseline and other data resources among which satellite images, DEM, and contour maps were imported to GIS for sewer shed delineation. The other baseline information such as population, manhole ground elevation was used for the calculation of sanitary flow and manhole invert which was carried out on Microsoft excel® sheets. All the information were finally imported to SWMM as an input for the simulation for the existing sewer network later on followed by LID deployed scenarios.

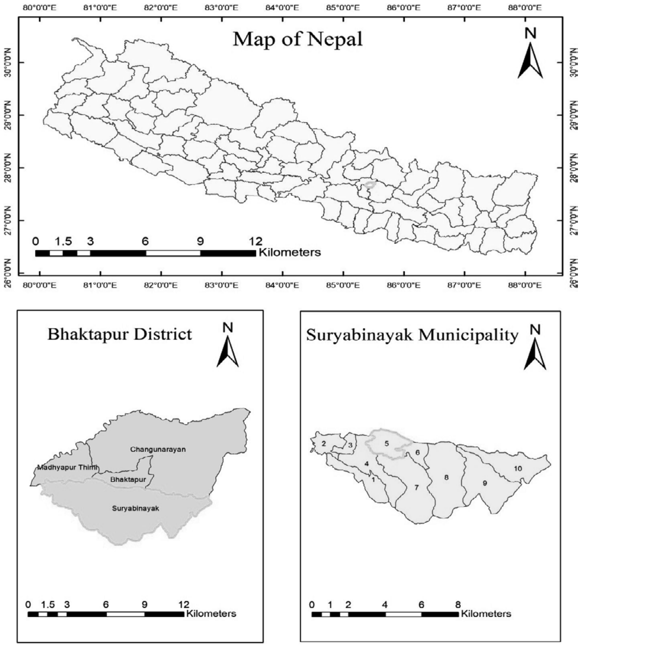

Figure 1: Study area; map of Nepal (top), map of Bhaktapur district with its municipalities (bottom left), map of Suryabinayak municipality with ward number five highlighted (bottom right)

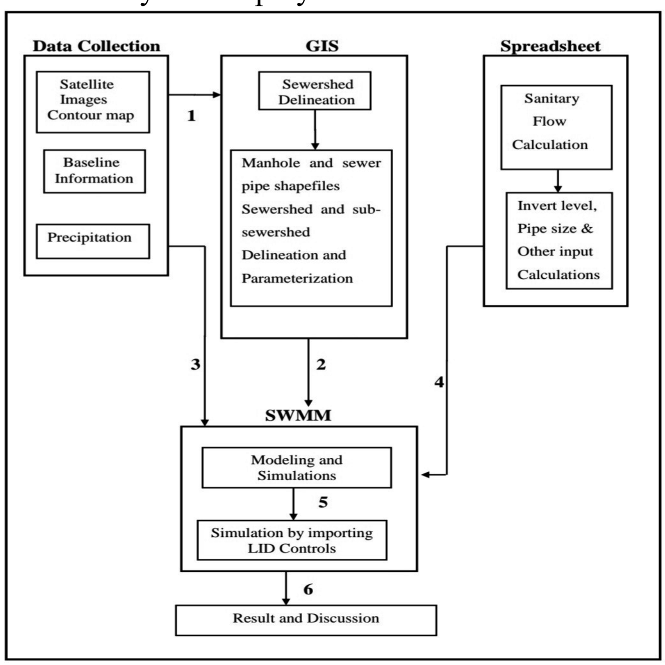

Figure 2: Flow chart of methodology (numbers in arrow represent the order of process)

Data Collection

The data required for the simulation (land use maps, satellite images, sewer dimensions and locations) were taken from multiple secondary sources and validated during site visits. The satellite images and contour lines were extracted from Google Earth Pro software, which provided images of 800 m spatial resolution and contour lines of 1 m. These images and contour lines were imported into GIS software (Arc GIS® v10.4.1, hereafter called GIS) and geo-referenced for spatial analysis and visualization. The shapefiles for the study area were taken from Survey Department, Nepal whereas a few were also manually created in GIS. However, since hourly (or higher temporal resolution still) precipitation data was not available in the Department of Hydrology and Meteorology (DHM) Nepal, the design storm analysis and Intensity Duration and Frequency (IDF) curve generation from data of nearby rainfall station was not possible. Hence, the IDF curve of Kathmandu Valley developed by Mishra & Herath (2012) at two years return periods was used as a design storm. The study had applied simple scaling theory for the derivation of short-duration rainfall

from the annual daily rainfall data of Kathmandu Airport Station from the year 1979 to 2003 to generate the IDF curve.

The latest updated population data of the study site was obtained from the Central Bureau of Statistics (CBS, 2011). The information about the existing sewer network was taken from the website of Sewer Asset Management System or SAMS (https://sams.softavi.com/). The information of latitude and longitudinal coordinates of the manholes were extracted from the SAMS whereas missing information of some manholes unavailable on the SAMS was collected manually through a GPS survey (Garmin etrex 10 GPS). Similarly, the ground elevation of manholes required for the manholes invert level calculation were extracted from Google Earth Pro software. The pipe slope and fall of the sewer were extracted from the design discretion of the existing sewer network in SAMS.

The sewer sheds were delineated in GIS software using the information provided from the aerial images, contour map and elevation data shown in Figure 3 (A). Each sewer shed was distinct from another with its unique outlet. Sewer sheds were further delineated to sub-sewer sheds by observing the slope of the area and the manhole location. The underdeveloped and agricultural areas have been neglected and only the built-up areas have been considered during sewer shed delineation. Altogether 8 sewer sheds and 239 sub-sewer sheds were delineated as shown in Figure 3 (B).

Sanitary sewage estimation is also a crucial step in the design of sanitary and combined sewer system. The average residential sanitary flow rate was calculated based on the number of people served, population density and per capita water demand of the residential zone. Sanitary flow for industrial, commercial, and institutional areas were calculated based on their average daily flow per unit area. The average flow was converted to peak flow by multiplying with the peak factor based on literature values (CHPEEO, 2013).

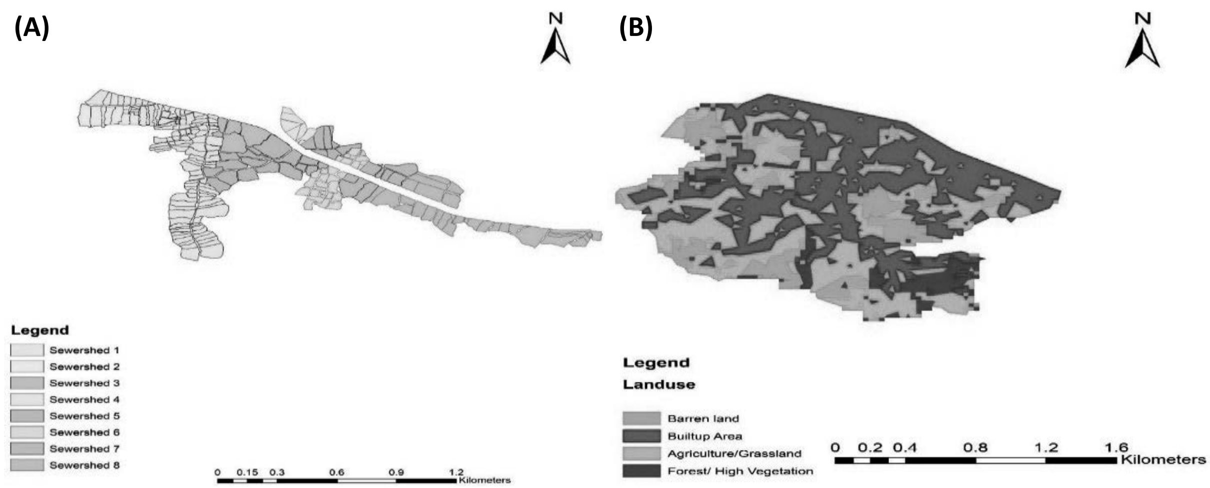

Figure 4: Sewer shed and sub-sewer shed delineation using GIS (A) and land use map (B) of Suryabinayak Municipality ward 5

Sewer Shed Characterization

For sewer shed characterization, the Landsat images of the year 2020 were first downloaded from the USGS website (https://earthexplorer.usgs.gov/) and the percentage imperviousness of each sub sewer shed was estimated by analyzing the land use map of the study site and the satellite images (Figure 5). The area of each sub-sewer shed was calculated in GIS; the slope was taken to be 0.5 and the flow width was twice the flow length for all sewer sheds. The roughness coefficient for the conduits was assumed to be 0.016 which is taken for fair concrete pipes (Metcalf & Eddy, 1981). The value of the depression coefficient was taken 0.2 for the previous layer because most parts of the study area were covered by lawn, agricultural lands and grassland and 0.05 for the impervious layer (Rossman, 2015). Likewise, the value of Manning's coefficient (n) was taken at 0.1 for the previous layer and 0.01 for the impervious layer.

Low Impact Development (LID) Scenarios

Three different LIDs, namely rain barrel, green roof, and rain garden were used in the SWMM model, each with contrasting features and working mechanisms. The rain barrel was chosen because it is easy to implement and maintain; the green roof was chosen because the roof occupies most of the impervious area in the study site, and the rain garden was chosen because it helps in groundwater recharge and filters pollutants carried by stormwater runoff. The parameterization of LID structures was mostly based on existing literature and the SWMM manual (Rossman, 2015; Rossman, 2010). The excess flow from all the three LID controls was modeled to be drained in the sub-catchment outlet. The number of green roofs, rain gardens and rain barrels to be used were determined according to the number of houses in each sub-catchment assigning one LID control per house for each LID scenario. LID controls were imported in altogether 1979 houses estimated through satellite images. The following sections describe the detailed scenarios considered in the study.

Scenario 1: A Baseline Scenario

The existing sewer network was simulated in the SWMM model without implementing LID. This case was used as the reference for comparison with other simulation scenarios.

Scenario 2: Rain Barrel Properties used in SWMM 5 as per (Rossman, 2015)

Each modeled rain barrel was assumed to have a capacity of 2000 L and 1295.4 mm diameter and each rain barrel had an area of 1.221 sq. m. The drain valve diameter was assumed as 30mm.

Scenario 3: Green roof as per properties used in SWMM v5.1 (Rossman, 2015)

The area of each green roof was taken 80 sq. m on average.

Scenario 4: Rain garden properties were used as per SWMM v5.1 (Rossman, 2015)

In the rain garden scenario, the modeled rain garden was assumed to have a size of 24 sq. m each. As rain barrels and rain gardens capture roof runoff only, and since roofs represented 75% of the impervious area in the study area, the share of the impervious area treated was taken to be 75%. Each sewer shed delineated earlier were simulated in SWMM and were analyzed based on their hydrological responses i.e., flooding and runoff through the sewer shed. The simulation was first done for the baseline scenario without any LID implementation which focuses on analyzing the existing condition of the sewer network. It was also the basis of comparison for all the other scenarios.

RESULTS AND DISCUSSIONS

Flooding Nodes

The runoff process of all the eight sewer sheds was simulated in SWMM to examine the node flooding over the design period of 20 yrs. The corresponding results of each sewer shed are listed in Table 1. All sewer sheds except SS- 7 were found to have a node that flooded. Thirty-eight manholes were flooded out of one hundred and eighty-nine manholes. This demonstrates that the existing sewer system might face CSO/ flooding events in future over 20 years.

The diameter of the pipe used in the study area ranges from 0.2-0.9 m. The smaller diameter of the pipe could be the reason for flooding in the nodes. However, the system design with a greater diameter of pipes becomes very expensive and thus unfeasible. Therefore, consideration of an appropriate size becomes conventional.

Table 1: Number of nodes flooding during storm events

Sewer shed	No. of nodes	No. of nodes that flooded
SS-1	82	12
SS-2	14	8
SS-3	3	1
SS-4	5	2
SS-5	19	3
SS-6	24	4
SS-7	6	0
SS-8	36	8

Effectiveness of LIDs in Reducing Flooding

The flooded seven sewer sheds were re-stimulated by importing three different LID controls in the SWMM model; LID practices were not imported in "SS 7" since it was not flooded. Then, the flood reduction and runoff capture potential of these three scenarios including the baseline scenario were compared for each sewer shed. The results of only one sewer shed 'SS 1' is depicted here as an example. The effectiveness of LID scenarios was analyzed by developing the following hydrographs and tables resulting from their hydraulic simulation. Figure 3 shows the runoff hydrograph and Figure 4 shows the flooding hydrograph of sewer shed 1 (SS 1).

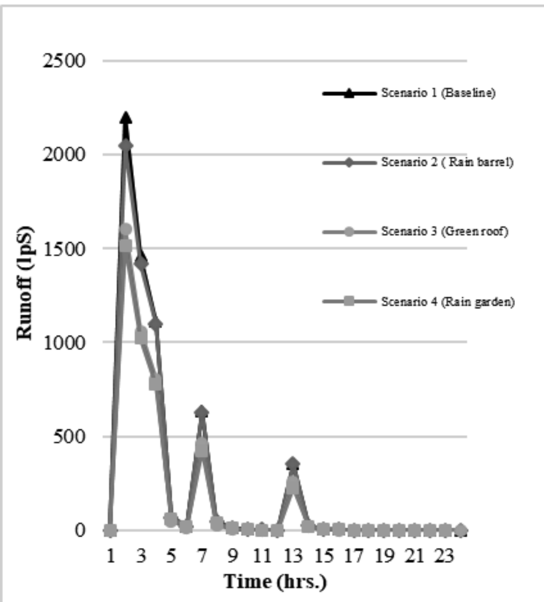

Figure 3: Runoff analyzed for different scenarios for sewer shed 1 (SS-1)

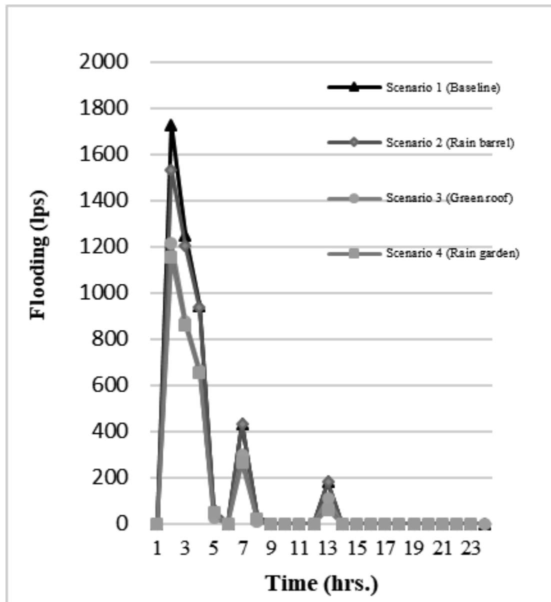

Figure 4: Flooding analyzed for different scenarios for sewer shed 1 (SS-1)

The runoff hydrograph (Fig. 3) of 'SS-1' shows that there has been 6.94%, 27.11% and 31.07% reduction in the peak runoff for the LID controls rain barrel, green roof and rain garden respectively when it was compared with scenario 1 (without LID). Similarly, the maximum flooding rate reduced by 11.28%, 29.58%, 33.24% for a rain barrel, green roof, and rain garden, respectively (Figure 4). The sewer sheds were also compared based on their flood volume and total outfall loading. The outfall loading and total volume of node flooding for each sewer shed were generated separately and a summarized result of those sewer sheds was developed to analyze for the overall sewer system. Tables 2 and 3 show the comparison of total flood volume and outfall loading for sewer shed 1 i.e.,' SS 1'.

Table 2: LID simulation result for total flood volume in the system

Sewer shed	Area [ha]	Avg. % reduction (RB) in total flood volume	Avg. % reduction (GR) in total flood volume	Avg. % reduction (RG) in total flood volume
SS-1	21.68	41.01	61.82	67.14
SS-2	3.39	7.27	45.49	53.08
SS-3	4.15	22.29	73.63	86.61
SS-4	2.12	44.44	60.12	80.69
SS-5	12.73	27.51	51.71	73.10
SS-6	3.69	62.02	87.98	92.30
SS-8	16.62	34.07	62.41	88.10

Table 3: LID simulation result for total outfall loading in the system

Sewer shed	Area [ha]	% Reduction (RB) in total outfall loading	% Reduction (GR) in total outfall loading	% Reduction (RG) in total outfall loading
SS-1	21.68	2.92	13.44	19.38
SS-2	3.39	1.25	19.38	30.66
SS-3	4.15	3.55	14.86	20.22
SS-4	2.12	0.18	9.74	27.79
SS-5	12.73	0.63	10.42	23.70
SS-6	3.69	2.37	26.04	40.74
SS-8	16.62	0.98	12.31	42.41

Tables 2 and 3 compare the average percentage reduction in total flood volume and outfall loading respectively in all seven sewer sheds (system) with LID deployments. The average reduction in outfall loading in the overall LID area ranges from 0.98 to 2.92% for a rain barrel, 9.74 to 14.86% for a green roof and 19.38 to 42.41% for a rain garden in pretending to baseline scenario. Similarly, the reduction in total volume ranges from 7.27 to 62.02%, 45.59 to 87.98 %, and 53.08 to 92.30 % for a rain barrel, green roofs and rain gardens, respectively. Analyzing the total volume reduction among all the sub-sewer shed 6 has higher LID effectiveness with the maximum volume reduction (62.02%, 87.98% and 92.30%) compared to all sub-sewer shed. However, in all cases, the rain garden boasted the maximum capacity for alleviating the flood volume and outfall loading.

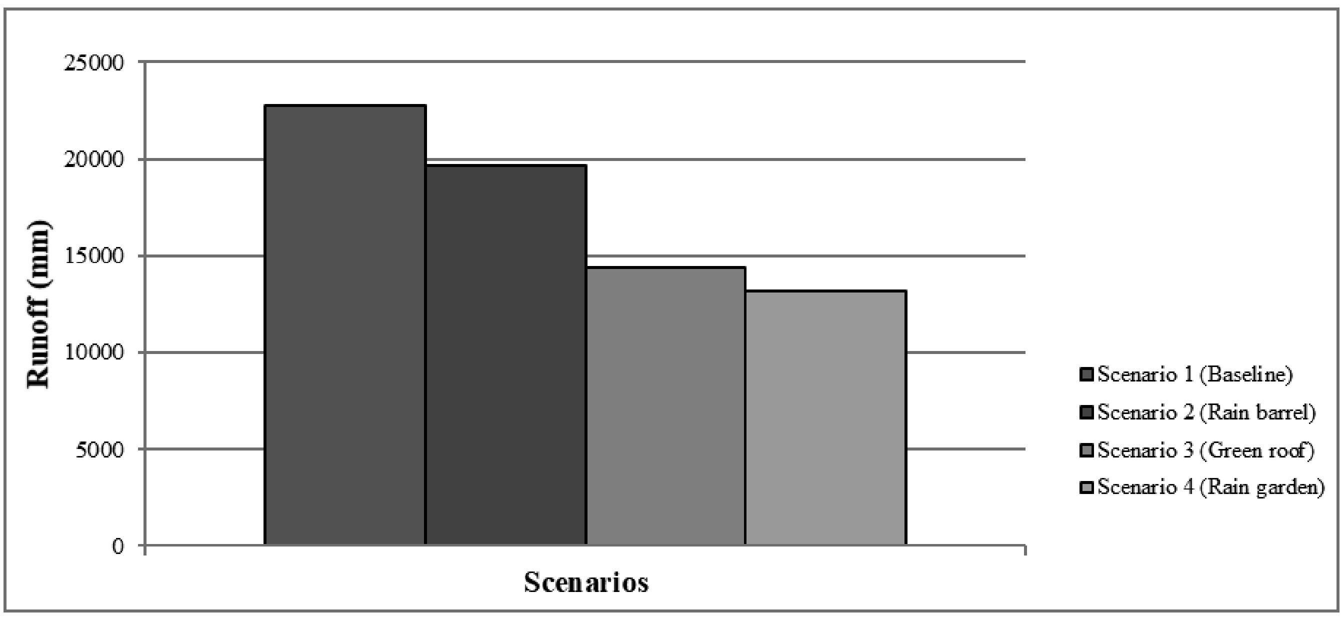

Figure 5: Comparison of total runoff from flooded sewer sheds under different scenarios

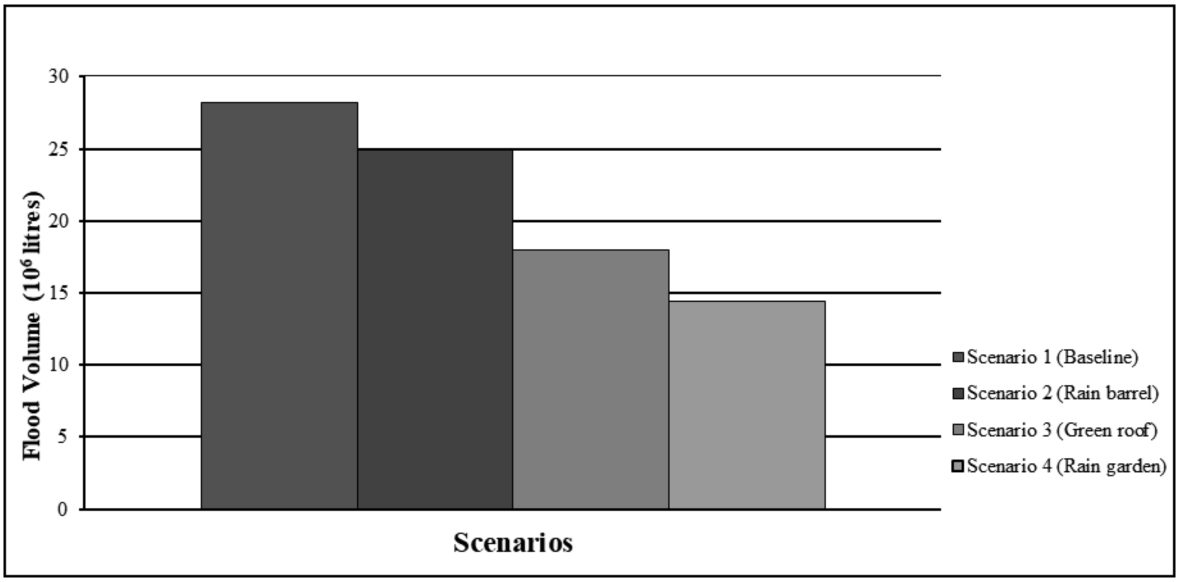

Figure 6: Comparison of total flood volume of flooded sewer sheds under different scenarios

Figure 5 demonstrates that runoff between the four scenarios differ remarkably. The runoff under Scenario 1 was 22780.44 mm while the total runoff under Scenario 2 was 14 % less than Scenario 1. Additionally, the runoff of Scenario 3 and Scenario 4 got reduced by 37 % and 42% respectively when compared to the baseline scenario. Figure 6 also illustrates the gradual decrease in total system flood volume by 12%, 36% and 49% by the use of rain barrel, green roof and rain garden.

The rain garden was found to be the most effective LID control on alleviating CSOs in response to the flood and runoff reduction potential. Green roof on the other hand served as the intermediate solution between rain garden and rain barrel. Despite having the same range of impervious area to be treated, rain barrel has very low runoff reduction potential compared to rain garden and green roof. This might be due to the small capturing area of the rain barrel compared to the rain garden. In addition, the rain garden decreases runoff more effectively through surface infiltration.

The results align with those available in published literature. For example, a study conducted by Heltzel (2019) in Davis Manor neighborhood, California depicted a 42% runoff reduction at two years return period of rainfall events after incorporation of rain gardens covering 0.232 hectares. Similarly, 40 % of storm runoff volume was found to be captured by fifty rain gardens established at Homes Lake watershed of Lincoln, Nebraska (Anderson et al., 2012). Montalto et al. (2007) has also performed similar research on an urban watershed of Brooklyn, New York by installing green roofs practices covering 47% of the study area and those green roofs were found to decrease the CSOs by 26%. Additionally, 29% and 55% of rooftop runoff reduction were observed in Vancouver, Canada and Shanghai, China after the deployment of green roofs (Roehr & Kong, 2010). Another study by Ahiablame & Shakya (2016) conducted at Sugar creek watershed also reported 5% to 19% annual runoff reduction through the use of rain barrels at different runoff capture potential of 25%, 50%, 75 % and 100% of total rooftop area of the watershed.

Our case study suggests that LID techniques are sustainable and effective means of green infrastructure for flood mitigation. LID controls also seem more reasonable and efficient as they can be easily installed on privately owned land within the limited private area and have significant reduction in CSOs. Furthermore, they are more resilient to an urban landscape as the majority of impervious land contributing to urban runoff are privately owned. Hence, the application of sustainable green infrastructure like; LID controls can certainly assist to cope with the problem of CSOs.

LIDs are also an efficient approach to adapt and mitigate the adverse consequences of climate change. LID installations replace the impervious surface with pervious green space which moderates the urban

temperature and reduce runoff flow through enhanced infiltration (Gill et al., 2007). Baniya et al. (2018) investigated the increasing Urban Heat Island (UHI) effect on Kathmandu Valley, Nepal and highlighted green roof installation as a promising and cost-effective technique to combat UHI and its adverse environmental impacts. LID strategies mimic the natural pre-development hydrological regime of an area and lessen stormwater runoff by increasing the share of infiltration, evapotranspiration, and surface/sub-surface detention and retention. The LID techniques significantly adjust the dynamic imbalance of the hydrological cycle through runoff volume reduction and groundwater protection (Feng et al., 2020). Hence, LID techniques can also serve as an attractive climate adaptation strategy for the urban environment.

This study has got few shortcomings due to the limited accessibility and availability of the precipitation-runoff data for sewer networks in urban areas, therefore, calibration and validation of the model could not be performed. However, validation of the results in terms of nodal flooding was done through field visits during the rainfall events and interactions with the residents living close to the area. As such it was found that the three nodes flooded belong among the same nodes that were found to be flooded in the model. Likewise, this does not invalidate elucidating the impact in terms of reducing the flow that can be brought by the LIDs on the test catchment. For the precipitation input, the IDF curve derived from twenty-five years rainfall record (1979 to 2003) of Kathmandu Airport Station provided by Mishra & Herath (2012) was referred to due to the unavailability of short term and hourly rainfall data at the nearest Bhaktapur rainfall station. Although the annual average rainfall of Katmandu Airport Station with 92.48 mm overcoming that of Bhaktapur Airport Station with 71.55 mm and the analysis of twenty-five years long precipitation data ensures validity and safety for the use of data, it is recommended to input the short interval rainfall time series of the nearest rainfall station for runoff simulation as far as possible.

It is acknowledged that the assumption that all flows from each sewer shed drain to their unique outlets and nodes which are not connected to other sewer sheds is highly simplistic. This assumption further led to not incorporating LIDs in sewer shed 7 as it didn't have any overflows. Had the simulation allowed for runoff from one sewer shed flowing into another, as is usually the case in the real world, it would have been necessary to incorporate LIDs in SS 7 since it could have led to overflows downstream sub-catchments. The simulation results, however, provide evidence of the utility of LIDs in mitigating CSOs when compared to a baseline scenario, bolstering its prospects for use in tandem with grey-infrastructure (sewerage system) to mitigate CSOs. Furthermore, this study compares the LID effectiveness based on flood and runoff reduction potential only. For further analysis, the cost-to-benefit analysis is suggested to be undertaken to include the cost-effectiveness for detailed comparison among the LID controls.

CONCLUSION

This research had performed a hydraulic evaluation of an existing sewer network through a rainfall-runoff simulation model SWMM. We first carried out a runoff simulation for the combined sewer network of Suryabinayak Municipality Ward-5, Nepal over the design period of 20 years using the SWMM. The simulation results indicating 38 flooded manholes out of 189 manholes demonstrate the inadequacy of the existing sewer network to sustain combined sewage load over 20 yrs. demanding the necessary up-gradation. In the next step, three different LID controls: rain gardens, rain barrels, and green roofs were further deployed and simulated on the same model to examine their flood and runoff reduction potential. The LIDs were compared by developing 3 different scenarios including an existing baseline scenario without LID implementation. From the simulation, Scenario 4 (Rain Garden) possessed better LID performance with the highest flood volume and runoff reduction compared to scenario 2 (Rain barrel) and scenario 3 (Green roof). Hence, findings from our study suggest that the incorporation of rain gardens seems the most efficient and feasible LID option for the study area as it can reduce the flood volume significantly by nearly 50%. LID controls can be a sustainable approach of flood management solution which attenuate urban flooding in a more natural and environmentally friendly way. They also hold better resilience to the urban climate and landscape. Hence, the existing sewer network of the Suryabinayak Municipality, ward

-5 can also adopt the LID techniques to lessen the storm and mitigate the risk of CSOs in the future. LID options also seem more viable due to their easy installation and economic feasibility as the incorporation of LIDs can save huge costs for the reconstruction and up-gradation of the sewer network. In addition, two or three LIDs can be deployed to increase the efficiency even more thus minimizing the requirement of up-gradation. However, the model needs to be further examined through its calibration and validation. The practical and economic considerations should also be accounted for the adoption of reasonable and suitable LID.

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REFERENCES

1. Ahiablame, L., & Shakya, R. (2016). Modeling flood reduction effects of low impact development at a watershed scale. *Journal of Environmental Management*, *171*, 81–91.
2. Aihara, Y., Shrestha, S., Kazama, F., & Nishida, K. (2015). Validation of household water insecurity scale in urban Nepal. *Water Policy*, *17*(6), 1019–1032.
3. Anderson, A. R., Franti, T. G., & Shelton, D. P. (2012). Hydrologic evaluation of established rain gardens in Lincoln, Nebraska. *American Society of Agricultural and Biological Engineers Annual International Meeting 2012, ASABE 2012*, *1*, 1–15.
4. Baniya, B., Techato, K., Ghimire, S. K., & Chhipi-shrestha, G. (2018). A Review of Green Roofs to Mitigate Urban Heat Island and Kathmandu Valley in Nepal. *Applied Ecology and Environmental Sciences*, *6*(4), 137–152. https://doi.org/10.12691/aees-6-4-5
5. CBS. (2011). *Central bureau of statistics*.
6. CHPEEO. (2013). *Part A: Engineering Chapter 3: Design and construction of sewers*.
7. Feng, M., Jung, K., Li, F., Li, H., & Kim, J. C. (2020). Evaluation of the main function of low impact development based on rainfall events. *Water (Switzerland)*, *12*(8).
8. Fu, G., Butler, D., Khu, S.-T., & Sun, S. (2011). Imprecise probabilistic evaluation of sewer flooding in urban drainage systems using random set theory. *Water Resources Research*, *47*(2).
9. Gersonius, B., Ashley, R., Pathirana, A., & Zevenbergen, C. (2013). Climate change uncertainty: Building flexibility into water and flood risk infrastructure. *Climatic Change*, *116*(2), 411–423.
10. Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: The role of the green infrastructure. Built Environment, 33(1), 115–133.
11. Gironás, J., Roesner, L. A., Rossman, L. A., & Davis, J. (2010). New applications manual for the Storm Water Management Model (SWMM). Environmental Modelling and Software, 25(6), 813–814.
12. Gong, Y., Chen, Y., Yu, L., Li, J., Pan, X., Shen, Z., Xu, X., & Qiu, Q. (2019). Effectiveness analysis of systematic combined sewer overflow control schemes in the sponge city pilot area of Beijing. *International Journal of Environmental Research and Public Health*, *16*(9), 1–18.
13. Heltzel, J. C. (2019). *Modeling low impact development (LID) stormwater facilities in an urban retrofit scenario: a case study at Davis Manor* [California State University]. http://csus-dspace.calstate.edu/handle/10211.3/208010
14. Hossain, S., Hewa, G. A., & Wella-Hewage, S. (2019). A comparison of continuous and event-based rainfall-runoff (RR) modelling using EPA-SWMM. *Water (Switzerland)*, *11*(3).

15. Huong, H., & Pathirana, A. (2013). Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam. *Hydrology and Earth System Sciences*, *17*(1), 379–394.

16. Luan, Q., Fu, X., Song, C., Wang, H., Liu, J., & Wang, Y. (2017). Runoff effect evaluation of LID through SWMM in typical mountainous, low-lying urban areas: A case study in China. *Water (Switzerland)*, *9*(6).

17. Metcalf, & Eddy. (1981). *Wastewater Engineering: Collection and Pumping of Wastewater* (G. Tchobanoglous (ed.)). McGraw-Hill.

18. Mishra, B. K., & Herath, S. (2012). *Investigating potential climate change impacts on rainfall intensity duration frequency curves in Kathmandu, Nepal*. *March 2017*.

19. Pradhan-Salike, I., & Pokharel, J.R. (2017). Impact of Urbanization and Climate Change on Urban Flooding: A case of the Kathmandu Valley. *Journal of Natural Resources and Development*, 56–66.

20. Prajapati, R., & Talchabhadel, R. (2018). What flooded Bhaktapur? *Myrepublica*. https://myrepublica.nagariknetwork.com/news/what-flooded-bhaktapur/ (accessed 10 August, 2020)

21. Roehr, D., & Kong, Y. (2010). Runoff reduction effects of green roofs in vancouver, BC, Kelowna, BC, and Shanghai, P.R. China. *Canadian Water Resources Journal*, *35*(1), 53–68.

22. Rossman, L. A. (2010). Modeling Low Impact Development Alternatives with SWMM. *Journal of Water Management Modeling*.

23. Rossman, L. A. (2015). STORM WATER MANAGEMENT MODEL USER'S MANUAL Version 5.1. *EPA/600/R-14/413b, National Risk Management Laboratory Office of Research and Development. United States Environmental Protection Agency, Cincinnati, Ohio.*, *September*, 352. http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100N3J6.TXT (accessed 10 August, 2020)

24. Rossman, L. A., & Huber, W. C. (2016). Storm Water Management Model Reference Manual. *The United States Environmental Protection Agency Office of Research and Development*, *III*(January), 231.

25. USEPA. (2000). Low impact development (LID): a literature review. In *Environmental Protection Agency* (Issues 841-B-00–005, p. 41).

GROUNDWATER-BASED INSTITUTIONAL DIMENSIONS AND THEIR ROLE IN NEPAL

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ABSTRACT

Groundwater is a fundamental resource for life. Groundwater as it occurs on the earth's surface in a form of springalso and could be abstracted on the earth's surface by constructingtube wells using different types of artificial pumps. There are at least four federal ministries and several provincial ministries have programs to utilize groundwater for different purposes, which mainly aim for irrigation and drinking including industrial, households and also for fulfilling ecosystems demand of water requirements. Groundwater,is, therefore, a natural resources which is equally important for sustaining socio-ecological system and their stability in hills and mountains of Nepal. There are several programs of various federal and provincial ministries uses groundwater for providing drinking and irrigation in Nepal are only making groundwater visible by bringing groundwater at the users' interfaces but this has given very least priority in water plan and water policy documents by mentioning groundwater inconjunctive uses.A strong interaction of groundwater with surface water affecting both water quantity and quality dependent watersheds in the Middle hills and Siwalik hills of Nepal. Therefore, groundwater keeps alive several streams in Nepal and a vital resources for preserving ecosystems and biodiversity in the Nepal Himalayas. Though, there are multiple institutions of different dimensions within all three governments but all the institution are doing investment in a single dimension of increasing water accessibility of water usersby exploitation of groundwater that is development of groundwater resources neglecting management and sustainability perspectives. Therefore, a strong step towards starting legal and governance framework under the federal government structure is required to make groundwater visible

KEYWORDS

Drinking, Federal, Groundwater, Mountain, Terai

1. Background

Groundwater resources play a major role in ensuring livelihood security across the world and can provide veryreliable high quality water source for human uses (UNESCO, 2009).As variations in hydrogeological setting of Nepal clearly show different groundwater potential in different physiographic regions of Nepal. This variation has led to the region of high groundwater potential in Terai, intermediate groundwater potential in valley filled terrain in midlands whereas a good potential in karstitied terrain of middle hills. It is estimated that about 42% of the Terai's farmers do have access to shallow tubewells(Central Bureau of Statistics, 2012).

Groundwater in Nepal occurs in alluvium aquifers of Gangetic plain (Shrestha, 2018). Millions of springs also comprises of groundwater system in hills and mountains that brings fresh water on the ground surface contributing for stability of socio-ecological systems in the area. Many rivers originating from non-snowfed watershed also survive receiving water from hard-rock aquifer, alluvium aquifer in mountain valleys and karstifiedaquifer system in hills and mountains. Springs are major water source for millions of people in the mid-hills of the Hindu Kush Himalayas (HKH) and supply more than 90% of water needs for domestic uses (Rathod et al, 2021).

As groundwater fulfil fundamental demand of fresh water for drinking water and also fresh water for various other purposes this is becoming a developing a new business opportunity for for middle class business communities. There are multiple stakeholders involve for exploitation of groundwater resources across Nepal. Groundwater is mainly used for drinking and irrigation as well as industrial purposes in Nepal, which includes all types of drinking water from individual households to municipal water supply, groundwater irrigation system from drilled wells as well drinking and irrigation water supply from spring sources in hills and mountains of Nepal. Since its wider scope and importance in multiple sectors, there are multiple stakeholders that are connected either directly or indirectly with groundwater resources in Nepal. The institutional dimensions of organizations related with groundwater resources of Nepal are looked through in the current federal context of Nepal in order to understand not only institutional dimensions but also for their working dimensionalities.

2. Institutions and their Dimensions

Depending on types of institutions and their dimensions, the institutions can be group into the following categories.

1.1 Government institution

i. Local Government (Municipalities)

This group includes all metropolitans, municipalities and rural municipalities. All these local governments and put activities for supplying drinking water by using groundwater from drilling wells and tapping spring water within their municipal area.

ii. Provincial Institutions

Regional offices are reconstituted within provincial government and became groundwater irrigation division offices in Nepal. All provincial governments allocate budget for exploitation of groundwater and development of groundwater dependent irrigation systems in various districts using both deep tube wells and shallowtube wells. In many areas, spring water is also tapped for fulfilling drinking water demand and supplying water for irrigation. In provincial government system, Divisional Irrigation offices within Ministry of Irrigation, Soil conservation and watershed and management offices within Ministry of Forest,Environment, Industry and Tourism, Ministry of Urban Development also have programs increasing accessibility of drinking water utilizing

groundwater by drilling and pumping but also by using spring water sources. Under the provincial ministerial system, department of forest and soil conservation offices are also doing conservation of water sources under the program called source conservation (“MuhanSamrakchan”). Which is also a part of task related with water conservation focusing on spring source areas.

iii. Federal Institutions

There are at least four current federal ministries, which are particularly related with Ministry of Energy, Water Resources and Irrigation, Ministry of Water Supply, Ministry of Urban Development and Ministry of Agriculture and Livestock Development directly link with groundwater and groundwater-relatedactivities in Nepal through their various intra-ministerial institutions. Among them, the Ministry of Energy, Water Resources and Irrigation allocates maximum budgets for irrigation using shallow and deep tubewells activities under various federal programsthat includes special regional programs and general programs.The most common point is that all four ministries of Federal Government of Nepal are doing investment mainly focusing for abstraction of groundwater from different sectoral budgets. Ministry of Energy. In addition, foreign aid supported projects within these ministries also play important roles for increasing water accessibility and availability of rural and urban people utilizing groundwater by constructing new wells and tapping spring waters and stabilising new water supply infrastructures.

iv. Water Supply Management Boards

After approval of Water Supply and Management Board Act 2063 BS, there are many new water supply management board are formed in emerging urban areas and cities. This type of water supply management board are already established in Kathmandu, Bharatpur, Hetauda, Dharan, which are respectively called Kathmandu Valley Water Supply Management Board, Bharatpur Water Supply Management Board, Hetauda Water Supply Management Board and Dharan Water Supply Management Board.

1.2 Non-Government Institutions

Many non-governmental organizations, private organizations, and several trusts exist in the country, which are also active for constructions wells, capturing spring sources and constructing water supply systems in rural semi-urban and urban areas.

This private sectors involvement in groundwater sectors covers wide users, which are industries related with drinking and beverages, drinking water suppliers, tanker water suppliers, bottle water and water jar suppliers. These types of industries and water suppliers are directly building groundwater production wells and supplying huge amount of groundwater in many districts that mostly focus in urban or semi-urban areas.

1.3 Academic Institutions

Tribhuvan University, Kathmandu University, Pokhara University, Mid-Western University, Far-Western University and Eastern University have undergraduate and graduate program related with water resources in general, which are mainly focus on engineering aspects and management aspects where groundwater topics are also included in the courses. Several water related research centres are also established to conduct research in water resources.

Central Department of Geology, Kirtipur, Kathmandu under the Institute of Science and Technology, Tribhuvan University is the only academic institution in the country which has focused course in hydrogeology. Central Department of Geology runs the course entitled “MSc in Geology with the Specialization in Hydrogeology”. This course focuses on building in-depth knowledge on groundwater science and its applied aspect and prepares human resource to work on groundwater sector of the country.

3. Institutional Dimensions and Groundwater Visibility

Though, groundwater covers about 90% contribution for drinking water and about70% contribution for irrigation, but this has created anintensification of groundwater uses. The institutions all involved in the various names of groundwater are joined hands together to bring groundwater on the surface for irrigation, drinking and households including other uses. Groundwater accessibility is increasedby brining groundwater at the user'slocation place by all institutions but not the visibility.

Groundwater visibility is not highlighted as the major part of groundwater governance is missing with the presence of strong institutions, governing act and rules. Similarly, visibility of groundwater by applying different management framework for a proper management of this limited resources for sustainable use is also lacking. There are different ministries, different departments that are allocating budgets for groundwater related tasks but all the institutions budget alignment remains in only single dimension that is dimension of groundwater uses but not for management and sustainability perspectives.

Nepal waterresources policy (2020), Irrigation policy (2014) and Nation water plan (2005) have mentioned groundwater highlighting its conjunctive uses and groundwater is separately and exclusively discussed. The sustainable use of groundwater for irrigation also proposed as part of the solution improving farmers' resilience to climate change the EIGP (Balwinder-Singh et al., 2019; Nepal et al., 2019).

4. Evolving Scenarios

As groundwater abstraction intensification is accelerating each year because of addition government budget for several groundwater-based priority irrigation system, an intense stress on groundwater aquifers is increasing. Groundwater dependent irrigation particular area focus government projects are increasing with installations of many new wells such as irrigation program in Dang, Chitwan, Terai and also a new upcoming program in Jhapa. Such new clustering of many new deep wells covering more than hundred meter drilled depth has developed a massive pressure on groundwater aquifers and also on shallow aquifer systems of various locations depending aquifer settings of the area. Building aquifers level understanding is becoming immensely important to protect groundwater resources against aquifer depletion both in quantity and quality. Sustainability of groundwater resources is a major concern for protecting natural recharge dynamics of groundwater systems in different physiographic regions of Nepal.

5. Conclusion

As the different institutions from all three government system, business houses and well as industries and private houses have major focus for increasing water accessibility by constructing shallow tubewells, deep tubewells and tapping spring sources in all physiographic regions of Nepal. Major dimensions of such institutions are federal, followed by provincial and then local. An intense pressure is on groundwater resources, which is the limited resources. An immediate stepshave to establish a suitable institution under federal structure is realized to overall manage groundwater resources of Nepal

REFERENCES

Balwinder-Singh, McDonald, A.J., Kumar, V., Poonia, S.P., Srivastava, A.K., Malik, R.K., 2019. Taking the climate risk out of transplanted and direct seeded rice: insights from dynamic simulation in Eastern India. Field Crops Res. 239, 92–103.

Central Bureau of Statistics,2012. Nepal: National sample census of agriculture 2011–2012.

Irrigation Policy. SinchaiNiti, 2070 (Nepali); Ministry of Irrigation: Kathmandu, Nepal, 2014.

Kathmandu, Nepal: National Planning Commission Secretariat, Government of Nepal.

National Water Plan. National Water Plan; Ministry of Energy: Kathmandu, Nepal, 2005.

National Water Resoruces Policy, 2020, Ministry of Energy, Water Resources and Irrigation

Nepal, S., Neupane, N., Belbase, D., Pandey, V.P., Mukherji, A., 2019. Achieving water security in Nepal through unravelling the water-energy-agriculture nexus. Int. J. Water Resour. Dev. 37, 67–93.

Rathod, R., et.all. (2021). Resource book on springshed management in the Indian Himalayan Region: guidelines for policy makers and development practitioners. New Delhi, India: International Water Management Institute (IWMI) New Delhi, India: NITI Aayog, Government of India New Delhi, India: Swiss Agency for Development and Cooperation (SDC)

Shrestha, S. R., Tripathi, G. N., & Laudari, D. (2018). Groundwater resources of Nepal: An overview. Groundwater of South Asia, 169-193.

UNESCO (2009). Third United Nations World Water Development Report: Water in the changing world. World Water Assessment Program.

MAGNETIC WATER TREATMENT PLANT IN PIPE LINE SYSTEM AND NEPALESE CONTEXT: A CASE STUDY OF WALING

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ABSTRACT

The water supply projects in Churiya range of Hindukush Region in Nepal are facing the calcium deposition problem. Water source containing high calcium causes the calcium deposition inside the conduit slowly and ultimately block the conduits. The government of Nepal (GoN) with the support of the Asian Development Bank (ADB) has been implementing Waling Water Supply and Sanitation Project in Syangja district which is one of the enhancement projects in the Third Small Towns Water Supply and Sanitation Sector Project (TSTWSSSP) to increase the ability of Water Users Committee and support/uplift the supply of existing water quality and quantity to the users. Major issues found during preparation of Benchmarking Report suggests to overcome the deficit supply of drinking water. A study was conducted during and after the installation of Magnetic Water Treatment process. Primary and secondary both the data were used during the research. Observation and in-depth interview with focus group discussion were the tools for the research. As a pilot project, Waling town has proposed an anti-scaling technique to control the calcium deposition in the pipeline. This is the general problem in high calcium content water and Waling is one of these suffering projects by calcium. To overcome this type of problem, Waling town project has been implemented to collect the technical idea in the Nepalese context this project will find out the success of the remedy of the calcium deposit. It was found that the deposited calcium on the wall of pipes was scoured, thus the result found satisfactory and could be replicated to other projects suffering from calcium deposition.

KEYWORDS

Anti-scaling, Calcium, Conduit, Water Supply

1. INTRODUCTION

1.1 Background

Calcium precipitated water creates the white stains on toilet, sink, dishwasher, and even dishes. Calcium deposits in pipes are common in homes that have hard water, or water with a high mineral content from magnesium, calcium, or potassium. This hard water can (and typically does) build up in drains and pipes and when left unresolved, can cause corrosion or blockages.

Rainwater is naturally soft, but when it falls and lands in areas with porous rock, it can become hard. This is because when the water passes over porous rock, such as chalk and limestone, it dissolves & picks up the rock's hard minerals (calcium & magnesium) and becomes hard.

To improve the present conditions of water supply and sanitation system, the Government of Nepal (GoN), with the assistance of ADB, has embarked on a three-pronged improvement strategy that includes:

- Improved Water Supply and Sanitation infrastructure
- Strengthened sector policy, regulatory and institutional capacity and service delivery
- Improved project implementation

To assist GoN in this endeavour, Asian Development Bank (ADB) has provided loans covering infrastructure investment and Strengthened sector policy, regulatory and institutional capacity, and service delivery.

Water Users and Sanitation Committee (WUSC) Waling, Syangja has made a pilot project for the quality and quantity improvement of existing system for its supply area in Waling municipality. The committee got the support from Third Small Towns Water Supply and Sanitation Sector Project which was supported by Asian Development Bank (ADB).

Effects Encountered

There are many problems associated with water hardness, including:

- Limescale in home, kitchen & bathroom.
- Bad tastes & smell in water
- Damaged electrical appliances
- Blocked taps and clogged showerheads
- Low water pressure in your home
- High energy bills
- Extra cleaning
- Clothes that appear untidy & dirty
- No soap lather when showering & washing
- Skin problems irritation including eczema

1.1 Problems Statement

Water flowing through the conduit has less friction requires smooth surface is one of the general principles of conduit requirements. Whenever high calcium content in the fluid and has to transport, the convener will be deposited by the settled calcium on the wall. The deposition will obstruct the waterways and increases the friction loss simultaneously blocks the conduit. This is the general problem in the project where there is high calcium contains in flowing water.

Figure1: shows the calcium deposition inside the pipes.
Source:https://www.waterworld.com/drinking-water/distribution/article/16192780/scale-factors-reducing-corrosion-in-pipelines-with-electronic-water-treatment

Figure 2: shows the calcium deposition inside the pipe inside the DI pipe

Figure 3: shows the calcium deposition fittings

There are several evidence noticed to search for an explanation to the white spots, film, and build-up which seems to be plaguing the glassware, faucets, showerheads, shower glass, and beyond. This ultimately generates nuisance deposit from drinking water.

1.2 Objective

The objective of the study is to familiarize with the anti-scale device to reduce or remove or mittigate the settling/precipitating of the calcium in the conduit. Subsidiary objective is to explore the idea of using an anti-scale device and share the results with the readers and researchers.

1.3 The Methodology

The methodology adopted to write the article by reviewing prevailing problems encountered in daily life and the piloting project with a short introduction on the Project. Primary and secondary both data were used during the research. Observation and in depth interview with focus group discussion were the data collection methodology for the research.

This research is socio-technical research rather than pure technical.

2 LITERATURES ON CALCIUM DEPOSITES IN CONDUITS

2.1 Reaction Seen by Calcium Carbonate

The exact role of kinetics and thermodynamics in calcium carbonate precipitation is not well understood. In calcite precipitation, there is an initial rapid growth surge of calcium carbonate that eventually slows to follow kinetic rate equations for the precipitation of calcium carbonate (Nancollas and Reddy, 1971). The most commonly proposed rate-limiting steps are CO_2 production. The number of available growth sites (Dove, P.M.;Hochella, 1993), system flow characteristics (Dreybrodt, W., Eisenlohr, L., Madry, B., and Ringer, 1997), and [Ca+2] saturation levels (Dove, P.M.;Hochella, 1993). Most researchers agree that the most important thermodynamic factor is the [Ca+2] in solution, but the most important kinetic factor is still debatable. For example, (K. et Al., 1989)and (D. et Al., 2002)had differing views about kinetic factors. (K. et Al., 1989)suggested that pH, specifically the [HCO_3 -], controlled the kinetics of calcium carbonate precipitation, but Dickinson et al. (2002) proposes that the kinetics of the growth reactions were controlled by CO_2 release. The genetic linkage between CO_2 release and [HCO_3 -] suggests that both authors may be correct. The [Ca+2] in solution intuitively is the most plausible kinetic factor affecting calcium carbonate crystallization. Varying the [Ca+2] relative to the saturation level within a system has a profound effect on growth rates and mechanisms of calcium carbonate. In solutions with saturation levels greater than 1 but less than 2, calcite exhibits two different types of growth. First, calcite growth is dominated by surface nucleation and coalescence, but transitions to a mechanism resembling spiral growth over time. In under saturated solutions, which are close to equilibrium, both surface dissolution and precipitation of calcium carbonate appear to occur simultaneously (Dove, P.M.;Hochella, 1993).Theoretically, one mole of CO_2 is produced for every mole of calcium carbonate precipitated. Thus, the rate at which CO2 can be produced and removed from the system can also be a rate-limiting step for calcium carbonate precipitation. In natural settings, aquatic organisms may have a positive effect on the rate of calcium carbonate precipitation as they consume CO_2 for vital processes (Lebron, I. and Suarez, 1996). (Nancollas, G.H. and Reddy, 1976) studied the effect of enzymes on the $HCO_3^- + H^+ \rightarrow H_2O + CO_2$ reaction rate to determine if CO_2 production could be enhanced. They observed that this reaction was enhanced in the presence of the enzymes, suggesting a linkage of CO_2 removal and carbonate precipitation. The exact role the enzymes play is not well understood. In the simplest of systems, one parameter may act as the rate-limiting step in calcium carbonate precipitation. In more complex systems, such as a natural system, many parameters may affect the rate at which calcium carbonate is precipitated from the solution. For example, in turbulent flow systems concentration gradients have a limited 7 ability to form, thereby homogenizing the surface fluid chemistry near the crystal surface and directly affecting the calcium carbonate precipitation rate. To further complicate issues, some studies observed a quasi-equilibrium phase before true chemical equilibrium. The quasi-equilibrium is represented in the data as a change in the slope of the concave parabolic curve of [Ca +2] in solution. Initially, [Ca+2] in solution decreases very rapidly, but slows over time. The quasi-equilibrium is maintained for a substantial period until the system reaches true chemical equilibrium (Dreybrodt, W., Eisenlohr, L., Madry, B., and Ringer, 1997). When comparing all these studies, it becomes apparent that calcium carbonate precipitation rate laws need to be carefully selected and applied (Teng, H.H., Dove, P.M., and De Yoreo, 2000). Analyzing the change in bulk chemistry of a system may not be the most accurate way to derive rate laws of calcium carbonate precipitation (i.e. discrepancies between rate law equations from studies of different scales). For example, (Goodarz-nia, 1979) and (Motamedi, 1979) observed an interesting phenomenon during their experimental precipitation of calcium carbonate that was not noted in any other study. When precipitating calcium carbonate, they observed that the overall crystal size increased with time until approximately 50 minutes after initial precipitation. After this time, the crystal sizes were observed to decrease, rather than continuing to grow. They could not explain this phenomenon, which could have been the result of the system reaching equilibrium, achieving slightly under saturated conditions, or transformation from one polymorphous phase to another with lower equilibrium solubility values.

White, Chalky, Spotty Build up

The white stuff we see is the result of minerals carried through the tap water.

Higher amounts of mineral deposits usually signify higher levels of water hardness. Hardness refers to the total amount of calcium, magnesium, and occasionally other minerals (e.g. silicate) in your drinking water. As water flows through limes tone and chalk in the environment, it dissolves calcium, carbonates, and magnesium that comprise the bulk of water hardness.

In areas with hard water, these minerals precipitate out of the tap water onto surfaces–which is why they're found most commonly on your faucets, showerheads, pots and pans, and anything that comes out of the dishwasher. It might hear this chalky white substance called "limescale", or "calcium buildup."

How to Remove Calcium Deposits from Pipes

Solving calcium build-up largely depends on the type of pipes you have in your home. For drain pipes that are blocked by mineral deposits, it can be as simple as using a drain cleaner like CLR or home remedies such as baking soda and vinegar. However, this is only a short-term solution as the mineral deposits will return if you don't get to the root cause.

Water supply pipes are tricker to descale as you don't want to introduce dangerous chemicals to your drinking water. Some homeowners look to other, safer alternatives such as vinegar or baking soda, but it would take large amounts of each to effectively remove large amounts of residue – not to mention a vinegar taste will linger in your pipes for a long time.

Long-Term Solutions

To reduce the chance of calcium build-up and protect your overall plumbing system, there are a few proven solutions.

Install PEX piping. Modern pipes made out of PEX plastic are more resistant to limescale than copper pipes. Installing a water softener system. These units remove or counteract the hard minerals from the water as it enters the home, thereby reducing the risk of calcium build-up in the plumbing. Some of the softeners are as hereunder.

Types of Water Softeners

1. Magnetic Water Softeners

Magnetic water softeners are pretty new on the market. These are advertised as a water softener alternative since they don't remove the hard minerals. Similar to salt-free systems, magnetic water conditioners neutralize the hard minerals to prevent them from bonding together, keeping them completely soluble. This means it will get all of the benefits of soft water, but these systems are much more affordable. They're also easy to install and it won't have to cut any pipes or even turn off the water. Instead, it will just wrap them around the existing pipes and the magnetic field will condition the water passing through. It may need to wire them into the home's electric though, so keep that in mind (Dahal, 2021).

This is one of those topics where a quick search on the Internet provides wildly varying results. There isn't much clear information about magnetic water treatment, and some sites say it doesn't work. There is a great deal of mis-information that seems to either make false claims or appear to be scientifically bogus, further complicating the search.

2. Salt-Based (Ion-Exchange) Water Softeners

Salt-based systems are the traditional type of water softener that most people are accustomed. They are meant to supply soft water to a system and feature high rates of flow. A resin inside attracts calcium and magnesium from the water and replaces them with sodium ions in a process called ion-exchange. When the resin runs out of positively charged sodium ions to exchange for the hard minerals in the water, it can regenerate the resin using salt. This requires a bit of regular maintenance on your part since regeneration will need to occur about once a week.
These systems completely remove the hard water causing minerals but little else. If there are chemicals or bacteria present in the water, then a salt-based softener won't remove it. Inside, the resin will last for many years. When it runs out, it can replace it for a low cost, enabling these systems to last for a very long time.

3. Conventional Salt-Based Water Softener

Conventional water softeners work with an ion-exchange process, where the calcium and magnesium in the water are replaced by sodium. This technology is proven, works consistently and does make water softer. It does reduce scale in your plumbing. One can find water softeners at local hardware or home improvement store.

Are there disadvantages of using a water softener? There are some, which include:
Softened drinking water contains sodium. The added sodium in your diet depends on how much you drink and how hard the incoming water is. When this is a concern, a non-softened water tap is used for drinking and cooking water, which adds to installation costs.

Soap can be harder to remove when washing hands with soft water, which results in a slippery feeling.

Conventional salt-based water softeners require periodic additions of salt to the system.

Conventional salt-based water softeners periodically run a regeneration process, where the removed calcium and magnesium is washed out, dumping water down the drain. The amount of wasted water depends on usage and the hardness of the incoming water.

While scale in plumbing clearly has bad side effects, sodium might also cause corrosion issues. Some studies suggest that the calcium scale can help prevent corrosion of steel parts.

Some people don't like the taste/feel of soft water. This is really a personal preference.

4. Salt-Free Water Softeners

Salt-free systems don't require the same continual upkeep that ion-exchange systems do since they don't need regeneration or salt. These systems don't actually remove the hard minerals from the water. Instead, they neutralize them to prevent them from sticking together and creating the buildup that leads to hard water.

Salt-free systems tend to be more expensive to get started with, but they cost less in the long run since it won't be constantly adding in large bags of salt and doing weekly upkeep. They also take up less space than salt-based systems since there's no need for an additional tank to take care of brining and draining. Despite being more compact, many salt-free systems feature a multi-stage filtration process that will do more than just neutralize minerals, removing unwanted impurities from the water like bacteria and chemicals.

5. Portable Water Softeners

Portable water softeners make it possible to have soft water wherever it go. These are perfect for travelers in RVs or travel trailers. They require no electricity and can go for several weeks between regenerations. When it need to regenerate a portable water softener, all it takes is a bit of regular table salt. Generally, no tools will be necessary to complete the process. They don't have the same level of water flow that it will get from a full-size softener, but they can easily supply water to a single bathroom or drinking water for several people. They're also much less expensive than their bigger brothers that are designed to supply a whole house.

6. Showerhead Water Softeners

Water softeners can be pretty costly since most are designed to supply an entire house with soft water. For many, this is too great of an investment. However, showerhead softeners make it much more affordable to get many of the benefits of using soft water. The hair and skin will feel much more hydrated and healthy. It will also have no more hard water spots on the shower walls and doors, and it will have less soap scum to clean up as well.
Showerhead water softeners install very easily by simply unscrewing the old showerhead and screwing on the new one. They use cartridge filters to condition the water and remove the unwanted minerals and more. The filter will need to be replaced about every two months. Some of these showerheads even feature vitamin filters that fortify the water with extra vitamins. Be careful about additives though. We tried some that also added scents and not everyone found them to be pleasant.

7. Reverse Osmosis Water Softeners

Reverse osmosis systems may not be generally thought of as water softeners, but they strip the water of all substances, including hard water causing minerals like calcium and magnesium. These systems often feature extra steps to re-introduce healthy minerals into the water so it will still have them for drinking. Generally built for under-sink installation, these units will often provide their own faucet from which it can have purified, soft water on tap. Reverse osmosis uses high pressure to force the water through an RO membrane that filters down to microscopic levels. The water will also be fed through several other filters on the way to ensure that all impurities are removed (Dahal, 2021).

3. Use of Magnetic Water Softeners

Even the Wikipedia article labels Magnetic Water Treatment as pseudoscientific, though there is a lot of contradictory information there. Here's what we know:

Magnetic Water Treatment directs water to pass through a strong magnetic field. By placing two strong neodymium magnets on either side of the incoming pipe, all the water passes through a strong, uniform magnetic field.

Magnetic water treatment does not remove any calcium or magnesium from the water. Technically, it is still just as hard as before it passed through the magnets. It claims to change the structure of the deposits that form, making them tend to be less apt to stick to surfaces.

3.1 Health Effect of Calcium

Water hardness is largely believed to be harmless to human health. Some research suggests that exposure to calcium and magnesium may have protective effects against cardiovascular disease, though the evidence is still not definitive. If water hardness causes any issues, it is usually aesthetic e.g. taste or staining on clothing or plumbing and appliance-related.

3.2 Effect at Home by Limescale

If the water has high water hardness, the scale can build up in your pipes–causing pressure and pipe integrity problems over time. This can negatively influence the water pipes to the home, but also the smaller pipes attached to appliances like washing machines, dishwashers, water heaters, and even the freezer's ice maker. It is likely noticed a lot of limescale around the home if this is the case, but testing the water for hardness can give you a clear indication of whether it needs to invest in a treatment solution.

3.3 Magnetic Water Softener uses Electromagnetic Coils

A magnetic water softener uses electromagnetic coils to separate certain particles that cause hard water, such as calcium and magnesium, from the water. It is effective only on water that comes within the reach of the magnets. Magnetic water softeners do not use salt to soften your water.

Each type of home water softener has its pros and cons. Here are the things to consider when deciding whether a magnetic water softener is right for you.

Positive Aspect of a Magnetic Water Softener

- As a rule, magnetic water softeners are a low-maintenance option to soften your water. They also offer the following benefits:
- Magnetic water softeners are less expensive than some of the other options on the market, including salt-based water softeners.
- They tend to have a long life – in fact, the filtration bed of a quality magnetic system may last as long as 40 years.
- Because they don't use salt, a magnetic water softener won't add any sodium to your diet and the water is safe to drink and use to water your plants.
- Depending on the hardness of your water, a magnetic water softener may be sufficient for your family's needs. However, Florida water presents some special challenges, so it's important to keep that in mind when making a decision.

Constrains of a Magnetic Water Softener

- No home water softener is perfect. While some may be attracted to the low cost and low maintenance of magnetic water softeners, it's important to understand where they might fall short.
- Magnetic water softeners don't actually remove minerals from water. Instead, they alter the chemical composition of the water to prevent scaling.
- While they do prevent some scaling, magnetic water softeners won't help prevent scaling in places where water sits for more than 48 hours, including your hot water heater.
- These home water softeners are not as efficient as some of the other options available because water must pass within range of the magnetic coils embedded in the sides of the filter to be softened.

There is little scientific evidence to suggest that magnetic water softeners are effective at softening water. The primary benefit of these systems is that they are inexpensive and easy to maintain. However, they do not offer the same rate of efficiency as the other systems available, including our Guardian Water Services water refiner, which uses four separate filtration methods to ensure the best water quality possible.

Ultimately, the most important consideration is ensuring that the water at home – whether it comes out of taps or sits in water heater – is safe for family to use. Choosing the right water softening system can improve the quality of water and saves money.

The first step is evaluating water to determine the best option for water needs. It could be start by contacting us to get a free water quality test today (Guardian, 2021).

A magnetic water softening device is attached to the waterline entering a property and is said to treat a household water supply and to reduce the build-up of limescale.

From Kasyap Engineering website we found the Anti-scaling device as follows

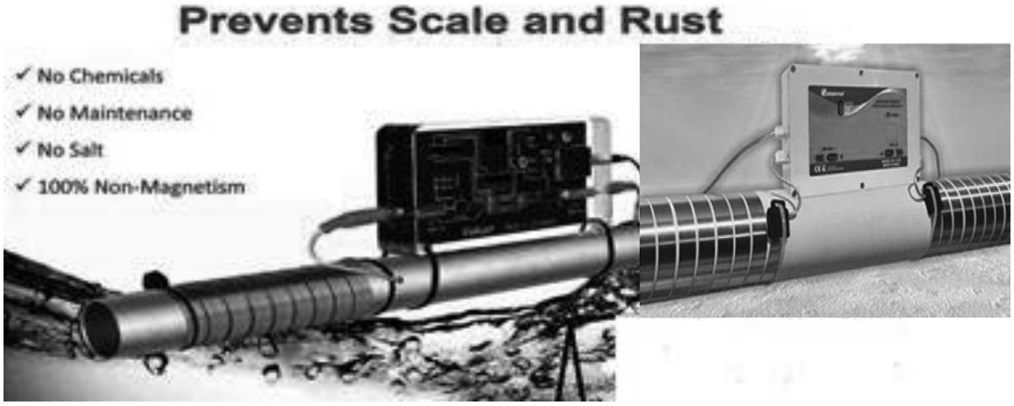

Figure 4: Anti-scale set up

Source: web site (Puretech, 2021)

Product Description

Against Scale and Rust the eco-friendly electronic water treatment. Kashyap-Impulse-Technology treats the water with electronic in pulses and does not use any chemicals or salt. The scale is washed away with the water as a fine powder. Anti-scale system contains programmed micro-processor to controls the unit to create electronic impulses inside the pipe by the bands wrap on the pipe. These bands create impulses inside the pipe which changes the shape of calcium crystals in the water. It works on all pipe materials iron, copper, steel, plastic, PVC, PE-X, Easy Do-it-Yourself installation without cutting the pipes. Anti-Scale System works with special conductive impulses and does not use magnetism.

Maintenance-Free

Benefits of anti-scale system -The electronic anti-scale system is the salt-free alternative to water softeners

- Secure reduction of scale deposit in the whole piping system.
- Less time and effort spent on repairs and maintenance in your home, hotel or factory
- Filters, shower nozzles and shower heads stay clean
- Faster cleaning of kitchen and bathroom
- Considerable savings in washing and cleaning agents
- Important minerals remain in the water for a healthy diet.
- Food and beverages keep their natural taste
- Skin feels less dry and softer

Feature

- No Maintenance, No Plumbing & Easy to Install
- Main pressure unaffected
- Little space required and safe.
- Low running cost, negligible power consumption.
- Effective on PVC, HDPE, Copper or Steel Pipe.

(Puretech, 2021)

Random Treatment Performance

The magnetic descaler has a variable performance as it can be altered by various factors, such as theflow of water or the type of installation. For this reason **it is not possible to measure the effectiveness of the treatment.**

Factors Affecting Magnet Performance

The Water Flow

The main disadvantage of a fixed magnetic system compared to other physical systems is that the performance of the system will depend on the speed of passage of water between the magnets

With a low flow rate the speed of the water will be slow and will not cause any crystallisation. his will cause the lime to continue to be deposited in the installations, especially in the heat exchangers.

On the other hand, if the flow is strong, the velocity of passage of water between the magnetic fields will be faster and the microcrystals will be created optimally.

Permanent magnet systems are suitable for industrial applications where water flows are fixed.

On the contrary, at the domestic level the results obtained are random because these systems are not adapted to variable flows.

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On the contrary, at the domestic level the results obtained are random because these systems are not adapted to variable flows.

Dropson at Variable Flows

Fixed magnet systems are not effective in applications where the flow rate is variable, as they depend on a number of factors and their performance is random.

On the other hand, the effectiveness of the Dropson water softener does not depend on the water flow rate. The magnetic fields are not fixed, but are driven by an electronic board and the frequency is electronically calibrated to operate even at very low flow rates.

Dropson Anti-Scale Technology

The result of fixed magnets is not reproducible as their efficiency varies according to various parameters. With Dropson each treatment cell is factory calibrated with extreme precision according to a flow curve (m^3/h) and a specific water hardness level (ºfH) for each model.

Drops on Professional Calculation Software

No special calculation is made for the installation of a fixed magnetic system. The magnets are installed according to the diameter of the tube, which is not correct, since it does not take into account the flow rate or the hardness of the water or the materials.

For its part, Dropson technology integrates a calculation and sizing software that allows devices to be selected according to needs and applications. The calculation takes into account the flow rate, the water hardness and the type of application according to the guidelines of the Spanish standard HS4.

Dropson Technical Support

Dropson supports the user with technical, after-sales, follow-up and maintenance advice.

Easy to Install Dropson Water Softener

The fixed magnetic system does not require any specific installation and does not require an electrical connection.

Dropson requires an installer and an electrical connection. It is installed at the general cold water inlet, accompanied by a sediment filter, as advised by water treatment professionals.

The performance of any anti-scale system can be affected by sediments and organic particles suspended in the water, whatever the model.

Removing the Limescale in Small Scale

Soak a cloth or towel in vinegar. Wrap it around the tap and let soak for 30-60 minutes depending on how much build-up. Remove, scrub, and wash with soap and water.

Removing Limescale in Toilet Bowl

If one has built up in the toilet, a little vinegar and baking soda will go a long way:
1. Turn off water to the toilet and then flush so the water level is low and one can see deposits
2. Spray or rub vinegar on deposits and let sit for 30-45 minutes
3. Then, scrub deposits with a toilet brush; if this works, turn the water on and end here
4. If there is still deposits found, add baking soda and scrub
5. This should do the trick, but a pumice stone scrub will take off any recalcitrant deposits.

Removing Limescale on Washing Machine

This method wastes a bit of water, but if the washer is filled with deposits, it may need to run through this routine:
1. Run a hot cycle (empty) with 1 cup of baking soda
2. Clean the inside of the washer with a cloth
3. Run a second hot cycle (empty) with 1 cup vinegar

Removing limescale from Pots and Pans

For heavily scaled pots and pans:
1. Fill pot with a 3:1 ratio of water to vinegar
2. Bring to boil, then turn off and let sit until water is warm
3. Use warm water with a sponge to scrub off the mineral deposits
4. Wash regularly

3.4 Lime Scale and Waling Piloting

Waling is one of the town of Syanga district of Gandaki province of Nepal. It is on the way Pokhara-Butwal Highway. Waling Municipality, the heart of Syangja, is a small valley covered with hills formed on 27 January 1997 by merging of the then three VDCs namely Waling, Dhanubase and Pekhubaaghkhor. In order to reform the structures of Municipalities and Rural Municipalities for the Federal Government System, it's area has been increased in 2073 BS by joining the previous Waling Municipality, Majhkot Shiwalaya VDC, Yeladi VDC, Jagat Bhanjyang VDC, Keware Bhanjyag VDC, Sirsekot VDC, Thumpokhara VDC, Chhang Chhangdi VDC(Ward No. 1,4-6), Malyangkot VDC (Ward No. 4), Tindobate VDC. It is a town and municipality in the western hilly region.

Figure 5: Waling town
Source: Waling Municipality, 2021

Water Supply System in Waling

In enhancement of Third Small Towns Water Supply and Sanitation Projects, Waling is one of the towns among; Bijuwar, Khalaga-Sittalpati, Tikapur, Adarshnagar /Bhasi, Mahendranagar and Baitadi including Waling itself, of western sector. These enhancement works were executed in 2020 in the support of Asian Development Bank (ADB). Waling was the First phase of Third Small Towns Water Supply and Sanitation Project. In the due time the water was deficit and facing calcination problems in the town.

Since, the project was enhanced by adding water quantity and piloting the magnetic water softening system.

Jaluke Solar Water Lifting Scheme

In depth interview Mr. Tarun Luniya from Pokhara said: The same technology as Waling town was used in Jaluke Solar Lifting Scheme, Syangja with support of KAAA (Kadoriee Agriculture Aid Association). This also worked on solar panel gave a good results for the community and they are very happy to see the results.

Teeka Resort using Anti-Scale

In depth interview Mr. Tarun Luniya from Pokhara said: a typical installment of Kashyap Anti Scale System at Hotel Teeka Resorts. This is a 2 year old newly built 3 star category hotel at lakeside, Pokhara. They were using shallow boring water and were regularly dozing 40kg salt in their Softeners (Ion Exchange Softener). They experienced loss in flow of water and they installed pressure pump to improve their same. But it did not work satisfactorily and they called their technician to review the treatment. When the technician opened up the pipe lines, they were shocked to see that hard scales had almost 80% chocked up their hot water line. The plumber didn't had any other option then to change the entire pipe line of the hot water, which now looked as impossible for the hotel owners, since they had invested so much in the interior decorations and bath rooms. This was the time they were introduced to Kashyap Anti Scaling System and they readily purchased it to see the effectiveness of it to their pipe lines. After 16 hours of installations of Anti Scaling System they experienced calcium contents (scales) coming out from the taps and asked to remove aerator. After 35-40 days of installation the pipe lines were miraculously cleaned, and that too without any other equipment and chemicals. Now the Hotel owner is happy to use this device from last 14 months without hurdles in their pipe lines. Now they are not using salt based Softeners. They are felt the economic and less manpower for the system.

Figure 6: Calcium Deposited pipe at Teeka Resort, Pokhara
Source: TarunLuniya, 2021

Results in Teeka Resort till September 2021

During the field visit the Author has visited the Teeka Resort (Three Star, Standard) at Pokhara Lake side and found the hotel owner was satisfied with the Kasyap Anti-scaling device as he had used since one year back. In depth interview was conducted with user for the performance, power consumption and effectiveness of the softener.

Figure7: Anti-scale from the Resort site
Source: The Author

The above photographs show the installed Anti Scale equipment in the Resort. The Resort owner was satisfied with the installed system.

Gandhinagar Thermal Power Station, at Gujrat

During the in depth interview with M. Lunia, he further added that Kashyap Anti Scaling System consists of Basically an Electronic Box with chips generating a frequency of 3 to 32 kHz, maximum consuming 3.75 watt, works on 24 Volts DC current, generating impulses which can travel upto 5-6 kms depending upon the pipe lines. It works on all Metallic and Nonmetallic Plastic Pipe lines. The Copper Bands which are given are self- insulated. No cutting or drilling of pipe is required to install the system. The system can work from 1” to 40” pipe lines. The world’s biggest installation is done on 63” pipe line at Gandhinagar Thermal Power Station, at Gujrat, India by Gujrat State Electricity Authority and is working satisfactory from past 3 years. The system comes on “plug and play” concept along with all the accessories required to fit the system, only an electrical plug socket is to be provided.

Piloting of the Water Softener in Waling

Magnetic Water Softener using Kasyap Anti-scale in this Waling town project.

Figure 8: Transmission Main
Source: TSTWSSSP

Supplied Anti Scale System was installed Kashyap Anti Scale System at Waling Water Supply and Sanitation Project (Enhancement with support of ADB) with anti-scale system was installed in GI water pipes size 150 mm diameter having a flow rate of range10 lps at Madi Khola. The system is to be installed on the outside pipe diameter without disturbing the water running system. The anti-scale system was installed with 24 Volts, 12 Volt battery, solar panel system Impulse Technology (Frequency Range: 3 – 32 kHz) on special conductive impulse. Impulse band wrap on the pipe treats water throughout the pipe uniformly. The anti-scale system should treat water with an impulse which is generated from the unit within the pipe that prevents scale in an eco-friendly way.

The input electric supply could also single-phase 230V, 50 Hz, it could work on any pipe material i.e. PVC, UPVC, Copper, Iron, Steel, PE, etc.

Equipment was connected as shown in the photographs on the ground connected with the main pipeline including required pipe fittings and protected with a noncorrosive net permanently fixed with base.

Figure 9: Technician Fixing Anti-scale System at Waling, Source: TSTWSSSP

The author had visited the project nearly one year back (April 2021) and found satisfactory results. The users were satisfy with this treatment. Presently, the author discussed with Water Users Committee regarding the workability and results of the applied system. It was learned that the deposited scale on the collector main was scoured by the system. The result found in the project was satisfactory(Dahal, 2021).

These parts could be re-evaluate and discuss after couple of years whether this unit is useful or not in sustainability aspect for such type of projects. This is a pilot project and new of this kind.

Benefits of this Type of Anti-Scaling

- Reduction in scale deposits in entire piping system
- Eliminates repairing efforts and maintenance
- Removes the existing scales in cooling tower
- Small space required and almost nil maintenance
- So salts an chemicals
- Softens the water
- Prevent new scaling
- Low running cost
- Negligible power consumption
- Protects from rust and corrosion

4. CONCLUSION

With the support of the Asian Development Bank (ADB), the Government of Nepal (GoN) is improving the present conditions of the water supply and sanitation system in Nepal's motorable towns, has embarked on a three-pronged improvement strategy that includes improved Water Supply and Sanitation infrastructure, strengthened sector policy, regulatory and institutional capacity and service delivery, improved project implementation

Within these scopes, Waling is one of the enhancement projects in the Third Small Towns Water Supply and Sanitation Sector Project (TSTWSSSP) to increase the ability of the Water Users Committee and support / up lift the supply of existing water quality and quantity to the users.

Natural rainwater is soft, but when it falls and lands in areas with porous rock, it can become hard. This is because when the water passes over porous rock, such as chalk and limestone, it dissolves & picks up the rock's hard minerals (calcium & magnesium) and becomes hard. Hard water is water that has a high mineral content and contains an excess of minerals including calcium and magnesium.

The high calcium content fluid transporting by pipe the conduit will be deposited by the settled calcium on the wall. The deposition will obstruct the waterways and increases the friction loss simultaneously blocks the conduit. This is the general problem in the project where there is high calcium contains water.

This project has been implemented to collect the technical idea in the Nepalese context as a pilot project, the success of the remedy of the calcium deposit. The outcome of the deposition of calcium till date was satisfactory i.e., no calcium deposition has been found in Waling Water Supply and Sanitation Project, Syangja. Further, research could provide more information in the water quality of the project to replicate the good practice in other similar projects to overcome the calcium incrustation problem.

REFERENCE

Dahal, D. R. (2021). *Resign Replacement*.

Dove, P.M.;Hochella, M. F. (1993). No Title. *Geochimica et Cosmochimica Acta*, *57*, 705–714.

Dreybrodt, W., Eisenlohr, L., Madry, B., and Ringer, S. (1997). *Precipitation Kinetics of Calcium Carbonate*.

Lebron, I. and Suarez, D. L. (1996). Calcite Nucleation and Precipitation Kinetics As Affected by Dissolved Organic Matter at 25°C and pH > 7.5. *Geochimica et Cosmochimica Acta*, *60*(15), 2765 – 2776.

Nancollas, G.H. and Reddy, M. M. (1976). The Crystallization of Calcium Carbonate: II. *Journal of Crystal Growth*, *35*(1), 33–38.

Teng, H.H., Dove, P.M., and De Yoreo, J. J. (2000). Kinetics of Calcite Growth: Surface Processes and Relationships to Macroscopic Rate Laws. *Geochimica et Cosmochimica Acta*, *64*, 2255 – 2266.

URL: https://pdf.indiamart.com/impdf/21330108030/MY-2237358/anti-scale-system.pdf

URL: https://www.indiamart.com/proddetail/kashyap-anti-scale-system-20786150048.html

WATER SUPPLY, SANITATION AND HYGIENE SITUTATION IN PROVINCE 1: REVIEW

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ABSTRACT

Province 1, situated in eastern Nepal, consists of 14 districts with an area of 25,905 square kilometres. As per 2011 census, the province has a population of 45,34,943 out of which more than 55 percent reside in the Terai districts of Jhapa, Morang and Sunsari. The government has made considerable efforts to improve water supply, sanitation and hygiene (WASH) situation in the province prioritising government budgeting for this sector at federal and provincial levels. Aim of this article is to describe the situation of water supply, sanitation and hygiene in Province 1 by analysing secondary data and information obtained from published and unpublished literature. About 98 percent of province population have access to basic water supply facilities whereas piped water supply coverage and safe water supply coverage stand at 57 percent and 19 percent respectively. All 14 districts have achieved open defecation free status in 2019 and basic sanitation coverage stands at 70 percent. Functionality of constructed water supply systems is a major issue as only 25 percent of Nepal's water supply systems are well functioning. The custodian agencies of province government and federal government should develop and utilise mechanisms to continuously review, refine and adapt their programming, approaches and technologies to make sure that water supply schemes are climate-resilient and sustainable and at the same time ensure access, quality, reliability and affordability of water supply systems.

KEYWORDS

Public Health, Water Supply, Sanitation, Hygiene, WASH, Sustainability

INTRODUCTION

In September 2015, Nepal adopted a new constitution with the goal of transforming the country from a centralized unitary state into a federal country toensure economic equality, prosperity, and social justice. The new constitution represents a paradigm shift in Nepal's sub-national government organization, structure, and operation. According to the constitution, there are three levels of government: the federal government in the centre, seven province governments that oversee each province, and 753 local governments in municipalities and rural municipalities. The constitution guarantees basic devolution of authority to the

various levels of government through exclusive and concurrent powers and responsibilities as set out in schedules five to nine of the constitution.(MOFAGA, 2019).

All three governments have been recognized as having concurrent powers over drinking water supply and sanitation. Provincial governments have been established in all seven provinces, with new organizational structures built with support of the federal government, and include several sectoral ministries as well as the office of the Chief Minister and the Council of Ministers. In this regard, situation of drinking water supply, sanitation and hygiene in Province 1, which constitutes of 14 districts and covers a total area of 25,905 square kilometres, is the focus of this paper. The province is home to 45,34,943 inhabitants, with a population density of 180 persons per square kilometres (CBS, 2011). More than 55 percent of this population is concentrated in the Terai districts of Jhapa, Morang and Sunsari. The 14 districts of the province are further divided into 137 local units consisting of one metropolitan city (Biratnagar), two sub-metropolitan cities (Dharan and Itahari), 46 municipalities, and 88 rural municipalities.

In comparison to the other six provinces, Province 1 has historically had a superior water supply, sanitation, and hygiene (WASH) status. A well-built road network, proximity to India (Sikkim, Darjeeling and Kolkata), better education levels among residents, and the adoption of traditional water conservation methods have all contributed to the province's upward rise of community-managed water supply and sanitation systems. Through organizations like the Gurkha Welfare Trust, the province's large Nepali British Gurkha community has also played a constructive role in improving rural drinking water supply and sanitary services.

Despite these good qualities, further efforts are needed to equip the residents of Province 1 with improved water supply and sanitation facilities. In 2021, the province has 98 percent access to basic water supply and 70 percent access to basic sanitation. Only 57 percent of people have access topiped water supply, and only 19 percent to safe drinking water (MOEAP, 2021b). Even though basic water supply coverage shows near universal access, existing system functionality remains a major concern, with only 25 percent of Nepal's total water supply schemes being functional (NMIP, 2014). Similarly, water quality has also not received much-needed attention, with most systems lackingadequate treatment units. Improved drinking water quality has long been a factor in improving people's quality of life and life expectancy (Angelakis et al. 2021), but the province government is still behind in providing treated drinking water to its citizens.

METHODS

This article is based on a review of published and unpublished research on water, sanitation, and hygiene in Nepal, with a particular focus on the 14 districts of Province 1. The condition of the province's WASH situation was assessed using published materials from the internet, as well as periodic and annual progress reports from key government agencies. Documents from the Provincial Ministry of Physical Infrastructure Development, Provincial Ministry of Economic Affairs and Planning, Provincial Planning Commission,Federal Ministry of Water Supply, Department of Water Supply and Sewerage Management, Ministry of Federal Affairs and General Administration and National Planning Commission were studied. Some data from the National Census 2011 and Nepal Demographic and Health Survey 2016 were also used as sources.

RESULTS

Adopted Goals (National, Provincial and SDG)

Nepal’s present Constitution has enshrined access to clean drinking water and sanitation as a fundamental right of every citizen. The federal government’s Fifteenth Periodic Plan (2019-2024) has set a vision for achieving a rapid and balanced economic development as well as prosperity, good governance and happiness of all citizens. Similarly, the province government’s First Periodic Plan (2019-2024) has set a vision for a clean, happy and prosperous province with specific sectoral targets in WASH. On the international front, Nepal’s commitment to Goal 6 of SDG has set a clear roadmap to increase access to improved water supply and sanitation by 2030.

Table 1: Nepal Fifteenth Periodic Plan WASH Targets (Source: NPC 2019)

	Indicator (percentage)	2019	2024
a	Access to basic level water supply	89	99
b	Access to medium-level and high-level service	21	40
c	Functional water supply coverage	62	99
d	Access to improved sanitation facilities	65	99
e	Basic sanitation coverage	99	100

Table 2: Province 1 First Periodic Plan WASH Targets (Source: PPC 2019)

	Indicator (percentage)	2019	2024
a	Basic water supply coverage	97	99
b	Piped water supply coverage	50	65
c	Safe (treated) water supply coverage	15	25
d	Basic sanitation coverage	62	82
e	Children below-5 affected with diarrhoea	17	10

Table 3: Nepal SDG Goal 6 Targets (Source:NPC 2017)

	Indicator (percentage)	2015	2030
a	Access to safe drinking water	15	90
b	Households with access to piped drinking water	50	90
c	Basic level water supply coverage	87	99
d	Households using improved sanitation facilities (not shared)	60	95
e	Urban households connected to sewer system	30	90

Present Status

Present status of water supply, sanitation and hygiene in Province 1 is optimistic with both the federal and province governments prioritising investment in this sector. Budget allocation has been considerable in the WASH sector in the last four years albeit lesser than to other vital social sectors like education and health. Construction of new water supply schemes along with repair, rehabilitation and extension of existing schemes have been implemented on a large scale by District Water Supply and Sanitation Offices. Community participation in water supply project construction which has been a mandatory policy requirement since the 1990s has played a big role in building ownership among communities and ensuring sustainability of the systems. A major impact ofincreased availability of drinking water and sanitation facilities in rural communities is seen with the decrease in Nepal's under-5 mortality rate from 54 percent in 2011 to 39 percent in 2016 (NDHS, 2016). Chart 1 illustrates how there has been a significant decrease in neonatal mortality, infant mortality and under-5 mortality rate in the 20-year period between 1996 and 2016.This can be attributed to an increase in government budgeting towards Nepal's rural water supply and sanitation sector following the International Drinking Water Supply and Sanitation Decade (1981-1990). Newly constructed public water taps benefited rural households in the hills who had previously relied on remote water sources, improving public health and hygiene.

The province government is likewise on track to accomplish its first periodic plan's targets. Basic water supply coverage has improved to 98 percent in the province, with 57 percent having access to piped water and 19 percent having access to clean water. Basic sanitation coverage has improved to 70 percent, and the percentage of children under the age of five who suffer from diarrhoea has decreased to 13 percent(MOEAP, 2021b).

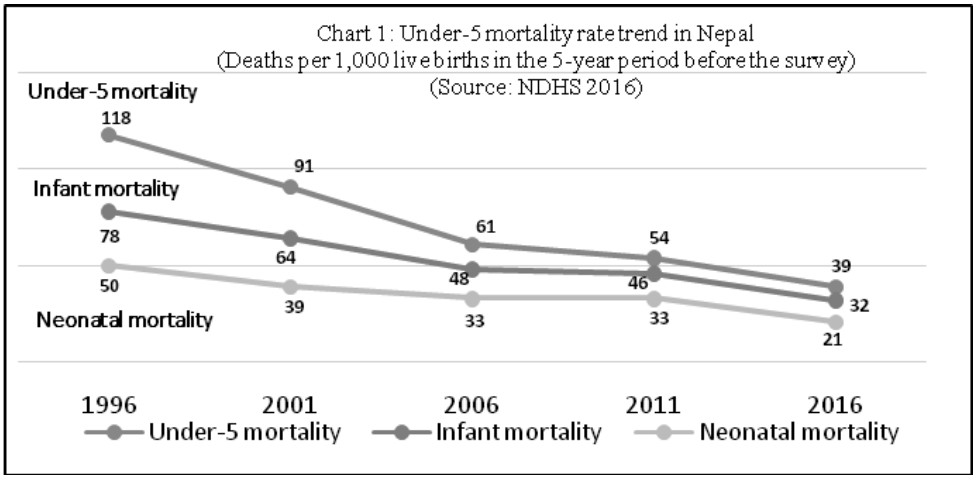
Table 4: Province 1 Medium Term Expenditure Framework 2021 Report (Source: MOEAP 2021b)

	Indicator (percentage)	2021
a	Access to basic water supply	98
b	Access to piped water supply	57
c	Safe water supply coverage	19

d	Basic sanitation coverage	70
e	Children under-five affected with diarrhoea	13

Table 5: Nepal Demographic & Health Survey Report (Source: NDHS 2016)

	Indicator (percentage)	2011	2016
a	Population using improved drinking water source	88.6	94.9
b	Population using treated drinking water	15.6	20.2
c	Population with access to improved sanitation facility (not shared)	36.7	64.6
d	Under-five mortality rate (deaths per 1000 live births)	54	39



Role of Provincial Government

The Ministry of Physical Infrastructure Development (MOPID) is the custodian agency for WASH in the province, with responsibility for public water supply, sanitation, and hygiene projects. Similarly, the Ministry of Social Development (MOSD), which oversees the province's education and health sectors, addresses WASH issues in schools and hospitals. The province government has been given the mandate to implement water supply projects for populations ranging between 500 to 1000 in the mountains, 3000 to 5000 in the hills and 5000 to 15000 in the Terai (OPMCM, 2019).

As per government data, MOPID implemented 815 water supply projects in its first year in 2018. This increased to 1235 in 2019, 1334 in 2020 and 1132 in 2021. It's worth noting that each water supply project is made up of one or more schemes that serve a specific area within the wider project area. In the same way, people who benefitted from completedwater supply schemes stood at 7965 in 2018, 40,841 in 2019 and 56,624 in 2020.

Table 6 illustrates the province government's yearly WASH budget financing trend, which shows that this sector receives roughly 15 percent of MOPID's annual budget each year. The allocated budget's absorption capacity, on the other hand, has been declining. The Covid19 pandemic, which halted development for the majority of 2019 and 2020, may be to blame for the lower spending.

Table 6: MOPID budget allocation & expenditure trend (In NPR billion)

(Source:MOPID 2021, MOEAP 2021a, MOEAP 2020)

Fiscal year beginning	Province 1 total budget	MOPID total budget	MOPID budget share %	WASH sector total budget	WASH budget share %	WASH budget expenditure	WASH budget expenditure %
2018	35.9	18.1	50.2	2.5	13.9	2.4	97
2019	42.2	19.9	47.1	3.4	17.2	3	87
2020	40.9	17.9	43.8	3.3	18.2	2.5	77
2021	32.5	13.2	40.7	1.7	12.8		

DISCUSSION

One of the biggest concerns in the province's public water supply and sanitation sector is the sustainability of water supply systems. Significant number of water supply schemes cannot function for the expected life span of 20 years (White et al. 2015). According to DWSSM (NMIP, 2014), only 25 percent of Nepal's water supply systems are operational, and only 68 percent can supply water to water taps throughout the year. A large number of the schemes are dysfunctional and poorly maintained, posing a direct threat to system accessibility, quality, reliability, affordability, and sustainability(Budhathoki, 2019).Functionality and sustainability of WASH facilities are influenced by aspects such as local user ownership, management capacity of the user committee, competent maintenance workers, and an operation and maintenance fund, among others. To operate and maintain the water supply systems, user committees collect tariffs and recruit human resources. The ability of user committees to manage water supply systems and keep the facilities operational is largely dependent on their management capabilities.

Water quality has been another concern in the province's community-managed water supply systems. In the hills and mountains, most water supply systems only provide basic level service (quantity up to 45 lpcd) and lack adequate water treatment units. As a result, during the monsoon season, surface water sources are more likely to convey turbid and biologically contaminated water. Similarly, in the Terai, only a few bigger water supply utilities that use deep bore pumps to extract groundwater have suitable treatment facilities for typical chemical contaminants like iron, manganese, and arsenic. Water utilities in urban centres that supply groundwater need to perform water quality tests at regular intervals to ensure impurities are within permissible limits. Adoption of Water Safety Plan (WSP) by rural water user committees is a commendable development that has helped maintain safe water quality from the source to the tap with preventive interventions at different stages of water transmission and distribution lines.

Another difficulty has been the increasing number of large-scale lifting water supply projects in the hills of Province 1. The increased demand for such technically complex lifting projects in such places could be due to the decreasing number of spring water sources and scattered rural settlements on higher elevations. As a result, various multi-stage lifting projects are under construction in the districts of Panchthar, Bhojpur, and Okhaldhunga. Apart from the high financial costs and technical complexity of such projects, the ability of rural water user committees to operate and maintain such electricity-dependent systems raises severe concerns about their long-term viability.

The NWASH system, a web-based management information system for the WASH sector, has proven to be a useful tool for compiling data on the province's water supply and sanitation systems. Data obtained through NWASH can serve as a stepping stone towards the much-needed evidence-based research and planning in Nepal's WASH sector. It will also give vital information for the preparation of municipal WASH plans, which have become a critical planning tool for local governments. Many municipalities in Jhapa, Morang and Sunsari districts are finalizing their WASH plans in order to attract future government funding based on the needs identified in their WASH plans.

Since the declaration of an open defecation-free Nepal in September 2019, the focus has switched to sustaining the ODF campaign's successes by implementing total sanitation initiatives.The province government has set a goal of completing total sanitation efforts in 50 of its local level wards by 2081, and it is on track to meet that goal, albeit slowly. One reason for the slow progress has been the non-functioning of District Water Supply, Sanitation and Hygiene Coordination Committees (DWASHCC) which had played a crucial role in the success of the ODF campaign (2011-2019). District Water Supply and Sanitation Offices must address this void by bringing on board community-based organizations, non-governmental organizations (NGOs), and international non-governmental organizations (INGOs) to promote total sanitation activities at the community level.

Faecal sludge management has been another major concern for the province government in regard to growing urban sanitation challenges. Groundwater contamination is a concern in cities like Biratnagar, Itahari, and Dharan, as well as fast emerging centers like Kakarbhitta, Birtamod, Damak, Belbari, and

Urlabari, as a result of careless faecal sludge disposal in surface water sources and open fields. The faecal sludge treatment plant in Charali (Jhapa), which was constructed and commissioned by DWSSM in 2019 is now in operation and is serving more than 5,000 households of three municipalities. This can be used as a model for other urban municipalities to follow in order to address the growing problem of faecal sludge management.

As the custodian agency for WASH in the province, the Ministry of Physical Infrastructure Development (MOPID) intends to accomplish both national and provincial goals of improving access to improved water supply and sanitation facilities for the province's citizens. Budget allocation trend in the sector shows that it has been given the much-needed priority in the last four years. However, the absorption capacity of the allocated budget shows a decreasing trend and this needs to be analysed and addressed by District Water Supply and Sanitation Offices during program formulation and implementation. The district offices should be sector-oriented and practicalby only demanding budget that can be effectively utilised. Demanding budget because of political pressure and unjustified bias will only reduce MOPID's overall budget efficiency adversely affecting its future allocations by the provincial and federal government. MOPID should ensure that project selection is demand-driven, and that any unwanted intervention is checked, particularly during the new fiscal year's budget formulation stage. MOPID's ongoing efforts to develop the Province Water Supply, Sanitation, and Hygiene Bill is a commendable step, and it could create the framework for regulating and streamlining future WASH initiatives in Province 1.

CONCLUSION

In conclusion, since the country adopted the federal system, Province 1 has made rapid progress inareas of basic water supply and sanitation coverage. In semi-urban and urban areas, efforts are being made to move from basic to medium and high-level water supply services, while the total sanitation program is gaining traction at the ward level. Since 2018, provincial budgeting in the WASH sector has been constantly prioritized, however the allocated budget's absorption capacity has been declining. The majority of the province's water delivery systems are poorly functioning and unable to provide water to users throughout the year. To ensure that projects are climate-resilient and sustainable, the province government should build mechanisms to review, refine and adapt its programming, approaches and technology on a regular basis. For elected officials, the timescale for municipal and province government choices is five years as per the Constitution, however for the WASH sector, it is necessary to consider several decades ahead with a strategic (five to ten years) or visionary timeframe (up to 50 years). The provincial and federal governments should work together to ensure access to improved WASH facilities, as well as to improve the quality, reliability, affordability, and sustainability of water supply services and progress toward achieving the provincial, national, and SDG goals for water supply, sanitation, and hygiene.

REFERENCES

Angelakis, A.N.; Vuorinen, H.S.; Nikolaidis, C.; Juuti, P.S.; Katko, T.S.; Juuti, R.P.; Zhang, J. &Samonis, G (2021). *Water Quality and Life Expectancy: Parallel Courses in Time*. Water 2021, 13, 752. https://doi.org/10.3390/w13060752

Budhathoki, C. B. (2019). *Water Supply, Sanitation and Hygiene Situation in Nepal: A Review*. Journal of Health Promotion, 7, 65-76.

CBS (2011).*National Population and Housing Census 2011*. Central Bureau of Statistics, Government of Nepal, Kathmandu.

MOEAP (2020). *Comparison of Province Government's Four-Year Budget Trend 2018-2021*, Ministry of Economic Affairs and Planning, Province 1, Morang.

MOEAP (2021a). *Province Government Annual Progress Report 2021*, Ministry of Economic Affairs and Planning, Province 1, Morang.

MOEAP (2021b). *Medium Term Expenditure Framework 2021-2024*, Ministry of Economic Affairs and Planning, Province 1, Morang.

MOFAGA (2019). Provincial and Local Governance Support Program, *Program Document 2019-2023*, Ministry of Federal Affairs and General Administration, Government of Nepal, Kathmandu.

MOPID (2021). *Periodic Progress Reports and Annual Progress Reports 2018, 2019, 2020, 2021*. Ministry of Physical Infrastructure Development, Province 1, Morang.

NDHS (2016), *Nepal Demographic and Health Survey 2016*. Ministry of Health, New Era and ICF, Kathmandu.

NMIP (2014). National Management Information Project 2014, *Nationwide coverage and functionality status of water supply and sanitation in Nepal*, Department of Water Supply and Sewerage, Kathmandu.

NPC (2017).*Nepal Sustainable Development Goals Status and Roadmap 2016-2030*, National Planning Commission, Government of Nepal, Kathmandu.

NPC (2019). *Fifteenth Periodic Plan 2019-2024*. National Planning Commission, Government of Nepal, Kathmandu.

OPMCM (2019). *Criteria for Classification and Distribution of Development Programs and Projects falling under the jurisdiction of Federal, Provincial and Local levels 2019*, Office of the Prime Minister and Council of Ministers, Government of Nepal, Kathmandu.

PPC(2019). *Province Periodic Plan 2019-2024*. Province Planning Commission, Province 1 Government, Morang.

White, P.; Badu, I.R. & Shrestha, P. (2015). *Achieving sustainable water supply through better institutions, design innovations and Water Safety Plans – an experience from Nepal*. Journal of Water, Sanitation and Hygiene for Development, 5(4), 625-631.

GROUNDWATER-BASED INSTITUTIONAL DIMENSIONS AND THEIR ROLE IN NEPAL

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ABSTRACT

Groundwater is a fundamental resource for life. Groundwater as it occurs on the earth's surface in a form of springalso and could be abstracted on the earth's surface by constructingtube wells using different types of artificial pumps. There are at least four federal ministries and several provincial ministries have programs to utilize groundwater for different purposes, which mainly aim for irrigation and drinking including industrial, households and also for fulfilling ecosystems demand of water requirements. Groundwater,is, therefore, a natural resources which is equally important for sustaining socio-ecological system and their stability in hills and mountains of Nepal. There are several programs of various federal and provincial ministries uses groundwater for providing drinking and irrigation in Nepal are only making groundwater visible by bringing groundwater at the users' interfaces but this has given very least priority in water plan and water policy documents by mentioning groundwater inconjunctive uses.A strong interaction of groundwater with surface water affecting both water quantity and quality dependent watersheds in the Middle hills and Siwalik hills of Nepal. Therefore, groundwater keeps alive several streams in Nepal and a vital resources for preserving ecosystems and biodiversity in the Nepal Himalayas. Though, there are multiple institutions of different dimensions within all three governments but all the institution are doing investment in a single dimension of increasing water accessibility of water usersby exploitation of groundwater that is development of groundwater resources neglecting management and sustainability perspectives. Therefore, a strong step towards starting legal and governance framework under the federal government structure is required to make groundwater visible

KEYWORDS

Drinking, Federal, Groundwater, Mountain, Terai

1. BACKGROUND

Groundwater resources play a major role in ensuring livelihood security across the world and can provide veryreliable high quality water source for human uses (UNESCO, 2009).As variations in hydrogeological setting of Nepal clearly show different groundwater potential in different physiographic regions of Nepal. This variation has led to the region of high groundwater potential in Terai, intermediate groundwater potential in valley filled terrain in midlands whereas a good potential in karstitied terrain of middle hills. It

is estimated that about 42% of the Terai's farmers do have access to shallow tubewells (Central Bureau of Statistics, 2012).

Groundwater in Nepal occurs in alluvium aquifers of Gangetic plain (Shrestha, 2018). Millions of springs also comprises of groundwater system in hills and mountains that brings fresh water on the ground surface contributing for stability of socio-ecological systems in the area. Many rivers originating from non-snowfed watershed also survive receiving water from hard-rock aquifer, alluvium aquifer in mountain valleys and karstifiedaquifer system in hills and mountains. Springs are major water source for millions of people in the mid-hills of the Hindu Kush Himalayas (HKH) and supply more than 90% of water needs for domestic uses (Rathod et al, 2021).

As groundwater fulfil fundamental demand of fresh water for drinking water and also fresh water for various other purposes this is becoming a developing a new business opportunity for for middle class business communities. There are multiple stakeholders involve for exploitation of groundwater resources across Nepal. Groundwater is mainly used for drinking and irrigation as well as industrial purposes in Nepal, which includes all types of drinking water from individual households to municipal water supply, groundwater irrigation system from drilled wells as well drinking and irrigation water supply from spring sources in hills and mountains of Nepal. Since its wider scope and importance in multiple sectors, there are multiple stakeholders that are connected either directly or indirectly with groundwater resources in Nepal.

The institutional dimensions of organizations related with groundwater resources of Nepal are looked through in the current federal context of Nepal in order to understand not only institutional dimensions but also for their working dimensionalities.

2. INSTITUTIONS AND THEIR DIMENSIONS

Depending on types of institutions and their dimensions, the institutions can be group into the following categories.

1.1 Government institution

i. Local Government (Municipalities)

This group includes all metropolitans, municipalities and rural municipalities. All these local governments and put activities for supplying drinking water by using groundwater from drilling wells and tapping spring water within their municipal area.

ii. Provincial Institutions

Regional offices are reconstituted within provincial government and became groundwater irrigation division offices in Nepal. All provincial governments allocate budget for exploitation of groundwater and development of groundwater dependent irrigation systems in various districts using both deep tube wells and shallowtube wells. In many areas, spring water is also tapped for fulfilling drinking water demand and supplying water for irrigation. In provincial government system, Divisional Irrigation offices within Ministry of Irrigation, Soil conservation and watershed and management offices within Ministry of Forest,Environment, Industry and Tourism, Ministry of Urban Development also have programs increasing accessibility of drinking water utilizing groundwater by drilling and pumping but also by using spring water sources. Under the provincial ministerial system, department of forest and soil conservation offices are also doing conservation of water sources under the program called source conservation ("MuhanSamrakchan"). Which is also a part of task related with water conservation focusing on spring source areas.

iii. Federal Institutions

There are at least four current federal ministries, which are particularly related with Ministry of Energy, Water Resources and Irrigation, Ministry of Water Supply, Ministry of Urban Development and Ministry of Agriculture and Livestock Development directly link with groundwater and groundwater-relatedactivities in Nepal through their various intra-ministerial institutions. Among them, the Ministry of Energy, Water Resources and Irrigation allocates maximum budgets for irrigation using shallow and deep tubewells activities under various federal programsthat includes special regional programs and general programs.The most common point is that all four ministries of Federal Government of Nepal are doing investment mainly focusing for abstraction of groundwater from different sectoral budgets. Ministry of Energy. In addition, foreign aid supported projects within these ministries also play important roles for increasing water accessibility and availability of rural and urban people utilizing groundwater by constructing new wells and tapping spring waters and stabilising new water supply infrastructures.

iv. Water Supply Management Boards

After approval of Water Supply and Management Board Act 2063 BS, there are many new water supply management board are formed in emerging urban areas and cities. This type of water supply management board are already established in Kathmandu, Bharatpur, Hetauda, Dharan, which are respectively called Kathmandu Valley Water Supply Management Board, Bharatpur Water Supply Management Board, Hetauda Water Supply Management Board and Dharan Water Supply Management Board.

2.2 Non-Government Institutions

Many non-governmental organizations, private organizations, and several trusts exist in the country, which are also active for constructions wells, capturing spring sources and constructing water supply systems in rural semi-urban and urban areas.

This private sectors involvement in groundwater sectors covers wide users, which are industries related with drinking and beverages, drinking water suppliers, tanker water suppliers, bottle water and water jar suppliers. These types of industries and water suppliers are directly building groundwater production wells and supplying huge amount of groundwater in many districts that mostly focus in urban or semi-urban areas.

2.3 Academic Institutions

Tribhuvan University, Kathmandu University, Pokhara University, Mid-Western University, Far-Western University and Eastern University have undergraduate and graduate program related with water resources in general, which are mainly focus on engineering aspects and management aspects where groundwater topics are also included in the courses. Several water related research centres are also established to conduct research in water resources.

Central Department of Geology, Kirtipur, Kathmandu under the Institute of Science and Technology, Tribhuvan University is the only academic institution in the country which has focused course in hydrogeology. Central Department of Geology runs the course entitled "MSc in Geology with the Specialization in Hydrogeology". This course focuses on building in-depth knowledge on groundwater science and its applied aspect and prepares human resource to work on groundwater sector of the country.

3. INSTITUTIONAL DIMENSIONS AND GROUNDWATER VISIBILITY

Though, groundwater covers about 90% contribution for drinking water and about 70% contribution for irrigation, but this has created anintensification of groundwater uses. The institutions all involved in the

various names of groundwater are joined hands together to bring groundwater on the surface for irrigation, drinking and households including otheruses. Groundwater accessibility is increasedby brining groundwater at the user'slocation place by all institutions but not the visibility.

Groundwater visibility is not highlighted as the major part of groundwater governance is missing with the presence of strong institutions, governing act and rules. Similarly, visibility of groundwater by applying different management framework for a proper management of this limited resources for sustainable use is also lacking. There are different ministries, different departments that are allocating budgets for groundwater related tasks but all the institutions budget alignment remains in only single dimension that is dimension of groundwater uses but not for management and sustainability perspectives.

Nepal waterresources policy (2020), Irrigation policy (2014) and Nation water plan (2005) have mentioned groundwater highlighting its conjunctive uses and groundwater is separately and exclusively discussed. The sustainable use of groundwater for irrigation also proposed as part of the solution improving farmers' resilience to climate change the EIGP (Balwinder-Singh et al., 2019; Nepal et al., 2019).

4. EVOLVING SCENARIOS

As groundwater abstraction intensification is accelerating each year because of addition government budget for several groundwater-based priority irrigation system, an intense stress on groundwater aquifers is increasing. Groundwater dependent irrigation particular area focus government projects are increasing with installations of many new wells such as irrigation program in Dang, Chitwan, Terai and also a new upcoming program in Jhapa. Such new clustering of many new deep wells covering more than hundred meter drilled depth has developed a massive pressure on groundwater aquifers and also on shallow aquifer systems of various locations depending aquifer settings of the area. Building aquifers level understanding is becoming immensely important to protect groundwater resources against aquifer depletion both in quantity and quality. Sustainability of groundwater resources is a major concern for protecting natural recharge dynamics of groundwater systems in different physiographic regions of Nepal.

5. CONCLUSION

As the different institutions from all three government system, business houses and well as industries and private houses have major focus for increasing water accessibility by constructing shallow tubewells, deep tubewells and tapping spring sources in all physiographic regions of Nepal. Major dimensions of such institutions are federal, followed by provincial and then local. An intense pressure is on groundwater resources, which is the limited resources. An immediate stepshave to establish a suitable institution under federal structure is realized to overall manage groundwater resources of Nepal

REFERENCES

Balwinder-Singh, McDonald, A.J., Kumar, V., Poonia, S.P., Srivastava, A.K., Malik, R.K., 2019. Taking the climate risk out of transplanted and direct seeded rice: insights from dynamic simulation in Eastern India. Field Crops Res. 239, 92–103.

Central Bureau of Statistics,2012. Nepal: National sample census of agriculture 2011–2012.

Irrigation Policy. SinchaiNiti, 2070 (Nepali); Ministry of Irrigation: Kathmandu, Nepal, 2014.

Kathmandu, Nepal: National Planning Commission Secretariat, Government of Nepal.

National Water Plan. National Water Plan; Ministry of Energy: Kathmandu, Nepal, 2005.

National Water Resoruces Policy, 2020, Ministry of Energy, Water Resources and Irrigation

Nepal, S., Neupane, N., Belbase, D., Pandey, V.P., Mukherji, A., 2019. Achieving water security in Nepal through unravelling the water-energy-agriculture nexus. Int. J. Water Resour. Dev. 37, 67–93.

Rathod, R., et.all. (2021). Resource book on springshed management in the Indian Himalayan Region: guidelines for policy makers and development practitioners. New Delhi, India: International Water Management Institute (IWMI) New Delhi, India: NITIAayog, Government of India New Delhi, India: Swiss Agency for Development and Cooperation (SDC)

Shrestha, S. R., Tripathi, G. N., &Laudari, D. (2018). Groundwater resources of Nepal: An overview. Groundwater of South Asia, 169-193.

UNESCO (2009). Third United Nations World Water Development Report: Water in the changing world. WorldWater Assessment Program.

EFFECT OF HYDRAULIC RETENTION TIME IN NITRIFICATION EFFICIENCY OF GROUNDWATER IN SINGLE AND SERIES REACTORS USING BIO-SPONGE MEDIA

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ABSTRACT

Clean and safe water plays a crucial role in the well-being of an individual. Groundwater is one of the major sources of water in Kathmandu Valley from ancient times. Threat to the groundwater remains in the Valley due to over-extraction and population growth. Nitrogenous contamination of groundwater is one of the serious issues of Kathmandu Valley. This research was conducted to determine the effect of Hydraulic Retention Time (HRT) in nitrification efficiency in single and series reactors using sponge media. Nitrification was performed at different HRT and the corresponding ammonium nitrogen conversion efficiency was found. pH in the range of 6.7 to 8.9 and Dissolved Oxygen (DO) in the range of 2.5 to 5.7 mg/l was recorded throughout the study period. The temperature of all the reactors was maintained constant at 25 ± 2^0C. The alkalinity of raw water influent ranges from 838 to 980 mg/l throughout the study period which was higher enough to carry out the nitrification.Influent ammonium nitrogen varied from 96.81 mg/l to 130.15 mg/l in the initial storage tank. For HRT 9.123 h, 1.824 h, and 0.912 h, the maximum ammonium nitrogen conversion was found at HRT of 9.123 h as the contact with oxygen and the bacteria is high during this period as compared to the HRT 1.824 and 0.912 h, respectively. The average ammonium nitrogen conversion efficiency was found to be 99.43%,66.03% and 35.96% at HRT of 9.123, 1.824 and 0.912 h, respectively for Series Reactor (RSE). For Blank Series Reactor (RSB), average ammonium nitrogen conversion efficiency was found as 27.41%, 13.01% and 9.38% at HRT 9.123, 1.824 and 0.912 h, respectively. The average ammonium nitrogen conversion efficiency of 96.55%, 61.72% and 28.36% were found at HRT 9.123, 1.824 and 0.912 h, respectively for Single Reactor (RS). For Single Blank Reactor (RB), average ammonium nitrogen conversion efficiency was found as 24.27%, 9.35% and 7.18% at HRT 9.123, 1.824 and 0.912 h, respectively. The ammonia conversion performance is found to be high in the case of series reactors as compared to the single reactor. The series reactors are more effective in the conversion of ammonium nitrogen than single reactors.

KEYWORD

Nitrification, groundwater, ammonia, sponge, single and series reactors

INTRODUCTION

Water is the most important need of living beings for their survival. For the quality of life, health, and well-being of an individual clean and safe water plays a crucial role. From ancient times groundwater

sources along with different surface sources fulfilled the water need of the Kathmandu Valley. The overexploitation, as well as the natural sources, affected the groundwater quality of Kathmandu Valley. Threat to the groundwater remains in the Valley due to over-extraction and population growth. About 45% of the population depends on groundwater to fulfill their water demand in Kathmandu Valley(Pant, 2011).Approximately half of the total water supply is achieved through Kathmandu Upatayka Khanepani Limited (KUKL) and the government authentic operator during the rainy season and 60-70% is derived from groundwater sources during the dry season(Ganesh, et al., 2018).

Contamination from sewage lines, septic failures, open pit latrines, leaching from landfill sites, and direct disposal of domestic as well as industrial wastes to the surface water source is the problem related to the groundwater of Kathmandu (Jha , et al., 1995).A study carried out to assess the groundwater quality map from the unconfined aquifer of Bhaktapur municipality found that the quality of groundwater exceeded the limit recommended by the National Drinking Water Quality Standard (NDWQS) on the basis of the value measured for nitrate, ammonia, and chloride in the majority of sample wells(Ganesh, et al., 2018).

Ammonia is present in groundwater from either degradation of naturally occurring organic matter or from manmade sources. The ammonia concentration in the range of 0.2 – 0.5 mg/l is found to be fatal for the fishes(Miladinovic & Weatherley, 2008). The presence of ammonia can result inthe formation of nitrite as an intermediate product during the oxidation process of ammonia. At a concentration of nitrite above 45 mg/l, it can result in anemia in infants and pregnant women(Odjadjare & Okoh, 2010).

Nitrification is a two-step oxidation process employing two different groups of bacteria, Nitrosomonas, which is an ammonia-oxidizing bacteria, and Nitrobacter which is nitrite-oxidizing bacteria(Metcalf & Eddy, 2003). The equation representing two-step oxidation of ammonia to nitrate is shown as follows:

For Nitrosomonas,

$$55NH_4^+ + 76O_2 + 109HCO_3^- \rightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3 \qquad ..\text{Eq. 2.1}$$

For Nitrobacter,

$$400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \rightarrow C_5H_7O_2N + 3H_2O + 400NO_3^- \qquad ..\text{Eq. 2.2}$$

The stoichiometric equations for nitrification are

$$NH_4^+ + 1.5O_2 \rightarrow 2H^+ + H_2O + NO_2^- \qquad ..\text{Eq. 2.3}$$

$$NO_2^- + 0.5O_2 \rightarrow NO_3 \qquad ..\text{Eq. 2.4}$$

It is found theoretically that while destroying 1 mgof ammonia to nitrate, 7.14 mg of alkalinity is consumed. For the maintaining alkalinity and pH control, quick lime (CaO) or calcium hydroxide ($Ca(OH)_2$) is often used.The formation of hydrogen ions (H^+) occurs in the oxidation process of ammonia to nitrite. Bicarbonate ions in raw water will neutralize the hydrogen ions of water if the pH is less than 8.3(Amatya, et al., 2011).

$$H^+ + HCO_3^- \rightarrow CO_2 + H_2O \qquad ..\text{Eq. 2.5}$$

It is found that for the oxidation of 1 mg of ammonia nitrogen to nitrate nitrogen, consumption of nearly 4.3 mg of O_2 and 8.64 mg of alkalinity in the form of HCO_3^- occurs(Amatya, et al., 2011).This research was conducted to determine the effect of Hydraulic Retention Time (HRT) in nitrification efficiency in single and series reactors using sponge media.

METHODOLOGY

Experimental Setup

The model is located within the premises of the Water Supply Department of the Institute of Engineering, Pulchowk. Two single reactors and the other two series reactorshaving equal volume of 3.976 l were

constructed by using a Polyvinylchloride (PVC) pipe. Each series reactor consists of three equal reactors in series. Out of two single reactors, one was filled with sponge media and another was left blank. Out of two series reactors, one seriesreactor filled with sponge media and another series reactorwas left blank. The reactor was operated in a continuous down-flow mode.The reactors were made by using Polyvinyl chloride (PVC) pipe columns with a diameter of 75 mm and height of 1.1m and 0.5m respectively for single and series reactors. The Bio-sponge media were cut into a circle of diameter 7 cm and woven in nylon thread by placing a circle alternately with the help of a 1cubic cm sponge.0.9 m and 0.3 m of bio-sponge media were placed in single and series reactors, respectively.The oxygen was supplied from the bottom of the reactor by injecting air from the air pump into the nitrification reactors using cylindrical air stones. A sampling port was provided in each reactor. The source of water used in the experiment is the deep boring water. This water was pumped to the overhead tank and fed to the reactors from the tank through pipes with flow control valves. An aquarium heater was placed in each reactor to maintain a constant temperature of 25^0C. To control temperature and prevent heat loss, the reactors were insulated from outside using foam. SOBO aquarium air pump (SB-30B) was used for the aeration.

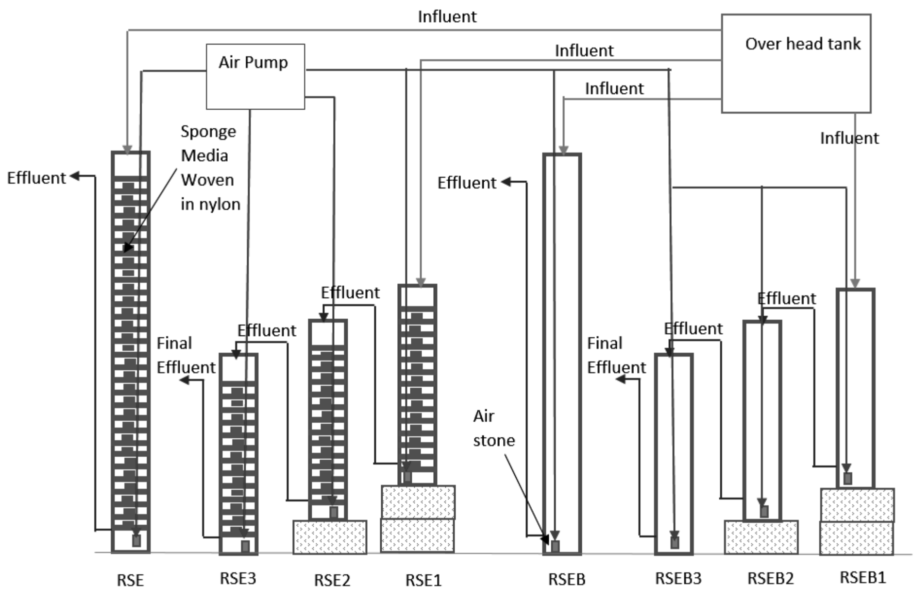

Figure 1: A schematic diagram of the model

Startup and Operation of Reactor

The seed nitrifying culture was obtained from the nitrification plant located at Jwagal water supply plant. The reactors were allowed to work in batch mode with a sufficient supply of air for 21 days for the proper growth of nitrifying bacteria. The reactors were then operated in continuous mode and the samples were collected for analysis.

Collection of Sample

The samples were collected every alternate day from the outlet pipe from each of the reactors for analysis. Thus, eight effluent samples from eight different reactors and one raw influent water sample, a total of nine water samples were collected for analysis.

Analytical Methods

Sample analysis was done using standard procedure. For the analysis, the laboratory of IOE, Pulchowk Campus was used. The temperature and DO of the samples were recorded at the site during sample collection. The pH, bicarbonate, NH_4-N, NO_3-N and NO_2-N were measured in the lab.

RESULTS AND DISCUSSIONS

pH

pH is one of the major factors affecting the nitrification process. The pH of the influent, as well as effluent, was varying throughout the study period. pH in the range of 6.7 to 8.9 was recorded throughout the study period. The nitrification process is more effective in this pH range.

DO

Nitrification is an aerobic process that requires sufficient oxygen to dissolve in water. The influent DO in groundwater was found in the range of 0.56 to 1.8 mg/l which is very low throughout the study period. Aeration was done to maintain the DO inside the reactors for nitrification. The DO was calculated in the range of 2.5 to 5.7 mg/l throughout the study. The nitrification process is satisfactory in this concentration of dissolved oxygen.

Temperature

Temperature is an important factor that affects the nitrification process. The temperature of the influent was recorded in the range of 10.2^{0}C to 27.2^{0}C.The temperature of all the reactors was maintained constant at 25 $\pm$2^{0}C throughout the study period.

Alkalinity

During the nitrification, alkalinity is consumed. The alkalinity of raw water influent ranges from 838 to 980 mg/l throughout the study period. The alkalinity of the raw water sample was higher enough to carry out the nitrification so an additional carbon source was not required for the bacterial process.

Ammonium Nitrogen (NH_4-N)

In groundwater, the concentration of ammonia varied from 96.81 mg/l to 130.15 mg/l in the initial storage tank and after passing through the nitrification reactors, it got reduced as the biological oxidation process occurs in the reactors. The analysis of ammonium nitrogen concentration reduction through the reactors has been done by observing raw water ammonia concentration for HRT 9.123 h, 1.824 h, and 0.912 h,respectively, which is shown in Figure 2, Figure 3 and Figure 4.Ammonia is the main parameter to be reduced through the nitrification process. The maximum conversion of ammonium nitrogenwas found to occur at the HRT of 9.123 h as the contact with oxygen and the bacteria is high during this period as compared to the HRT at 1.824 and 0.912 h, respectively.The ammonia conversion performance is found to be high in the case of series reactors as compared to the single reactor.

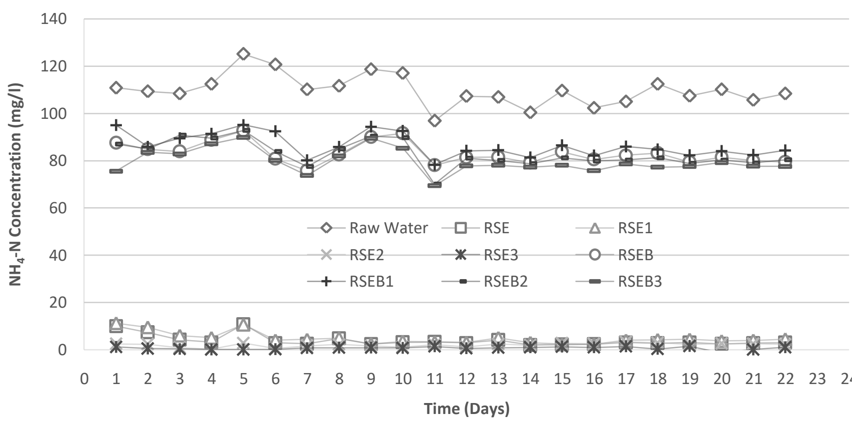

Figure 2: NH_4-N concentration at HRT 9.123 h

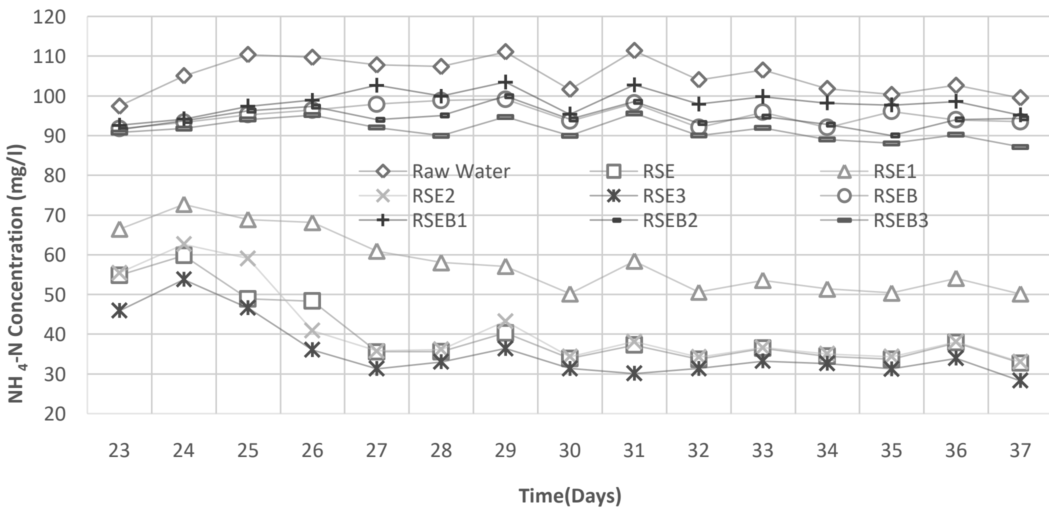

Figure 3: NH_4-N concentration at HRT 1.824 h

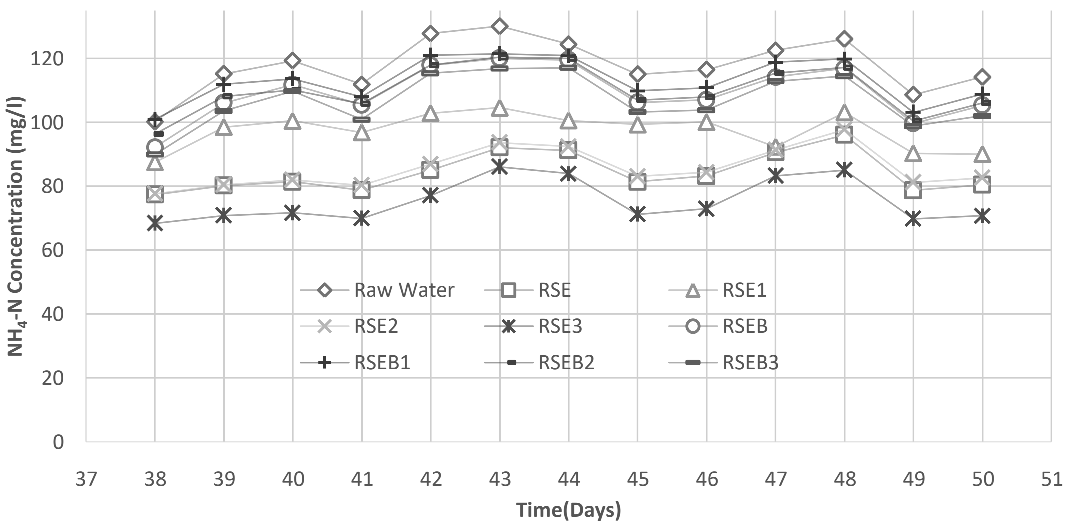

Figure 4: NH_4-N concentration at HRT 0.912 h

Efficiency

The ammonium nitrogen conversion efficiencyfor single and series reactors for HRT 9.123, 1.824 and 0.912 h are shown in Figure 5, Figure 6 and Figure 7 respectively. The average ammonium nitrogen conversion was found 99.43 % and 96.55% in series and single reactor with sponge media at HRT 9.123 h.The average ammonium nitrogen conversion efficiency was 27.41% and 24.27% in Blank series and single reactor respectively at HRT 9.123 h. The average ammonium nitrogen conversion efficiency is 66.03%,61.72%,13.01% and 9.35% for series with media, single with media, blank series and blank single reactor at HRT 1.824 h, respectively. For HRT 0.912 h the average ammonium nitrogen conversion efficiency was found 28.36%, 35.96%,7.18% and 9.38% for the effluent from Single Reactor (RS), Series Reactor (RSE), Blank Single Reactor (RB) and Blank Series Reactor (RSB). The conversion efficiency of ammonia is found to be higher in the reactor in the HRT of 9.123 h. Low conversion efficiency was observed at HRT of 0.912 h. This is low retention time allowing less time of contact of water with oxygen and the bacteria. The conversion percent of ammonia was observed higher in the case of higher ammonia load in the reactor as compared to low ammonia concentration and in high HRT in the reactor.

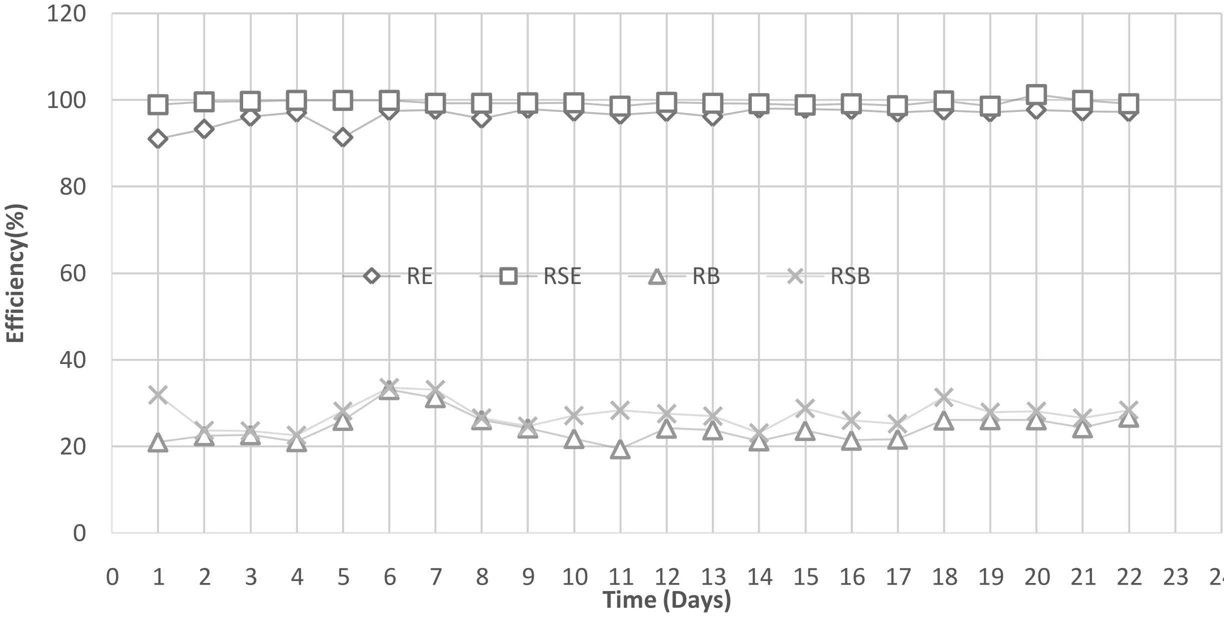

Figure 5: Ammonium- Nitrogen conversion efficiency for HRT 9.123 h

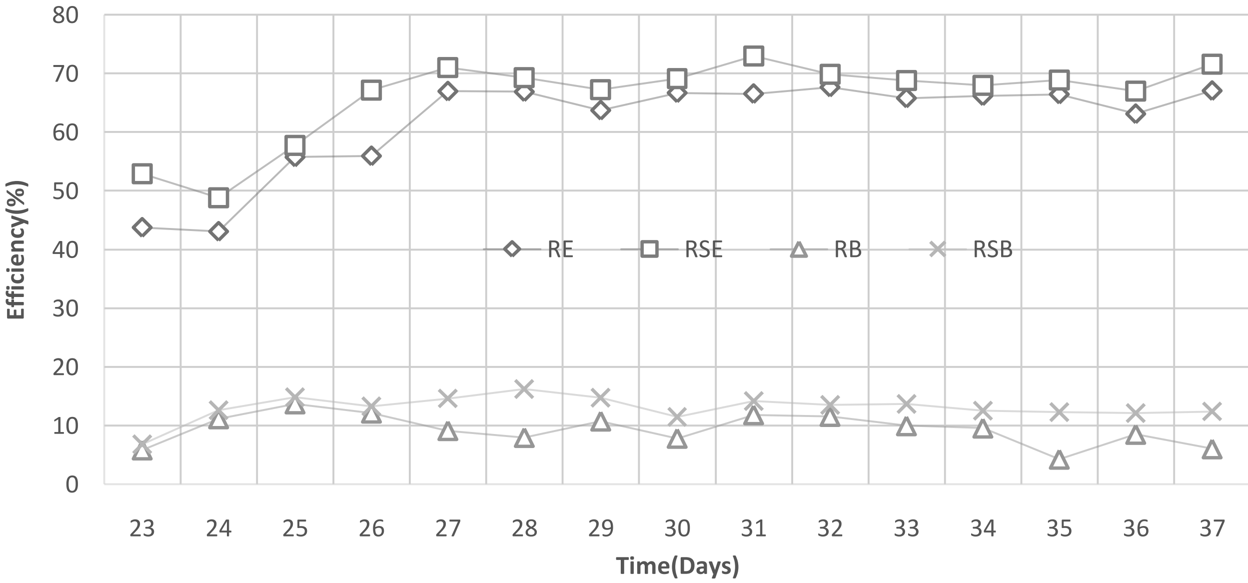

Figure 6: Ammonium- N conversion efficiency for HRT 1.824 h

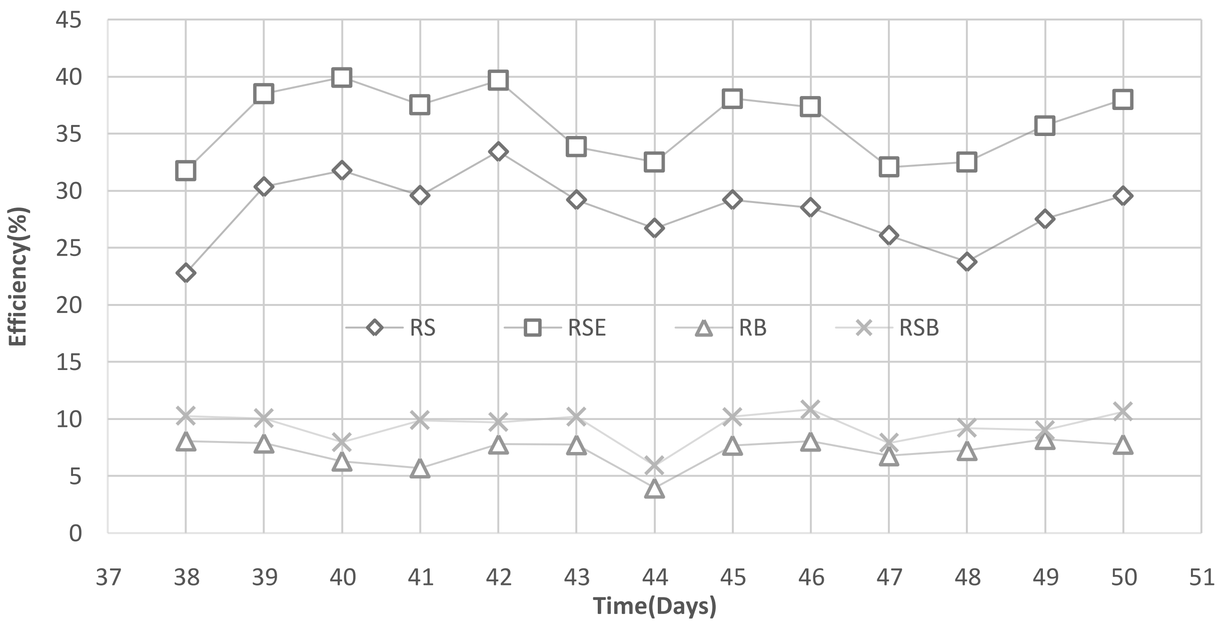

Figure 7: Ammonium-N conversion efficiency for HRT 1.824 h

CONCLUSION

pH in the range of 6.7 to 8.9 and Dissolved Oxygen (DO) in the range of 2.5 to 5.7 mg/l was recorded throughout the study period. The temperature of all the reactors was maintained constant at 25 ± 2^0C throughout the study period.The alkalinity of raw water influent ranges from 838 to 980 mg/l throughout the study period. The alkalinity of the raw water sample was higher enough to carry out the nitrification. The concentration of ammonium nitrogen varied from 96.81 mg/l to 130.15 mg/l in the initial storage tank. The maximum conversion of ammonium nitrogen is found to occur at the Hydraulic Retention Time (HRT) of 9.123 h as the contact with oxygen and the bacteria is high during this time as compared to the HRT 1.824 and 0.912h,respectively.The average ammonium nitrogen conversion efficiencywas found to be 99.43 %,66.03% and 35.96% at HRT of 9.123, 1.824 and 0.912 h, respectively for Series Reactor (RSE). For Blank Series Reactor (RSB), average ammonium nitrogen conversion efficiency was found as 27.41%, 13.01% and 9.38% at HRT 9.123, 1.824 and 0.912 h, respectively.The average ammonium nitrogen conversion efficiency of 96.55%, 61.72% and 28.36% were found at HRT 9.123, 1.824 and 0.912 h respectively for Single Reactor (RS). For Single Blank Reactor (RB), average ammonium nitrogen conversion efficiency was found as 24.27%, 9.35% and 7.18% at HRT 9.123, 1.824 and 0.912 h, respectively.The ammonia conversion performance is found to be high in the case of series reactors as compared to the single reactor. The series reactors are more effective in the conversion of ammonium nitrogen than single reactors. In addition, ammonium nitrogen conversion efficiency is higher for higher HRT due to the higher time of contact of water with oxygen and the bacteria.

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REFERENCES

1. Amatya, I. M., Kansakar, B. R., Tare, V. & Fiksdal, L., 2011. Role of pH on biological Nitrification Process. *Journal of the Institute of Engineering, 8(1-2),* pp. 119-125.
2. Ganesh, R., Koju, R. & Prajapati, R. R., 2018. Assessment of groundwater. *Journal of Science and Engineering,* Volume 5, pp. 43-50.
3. Jha , M. G. et al., 1995. The assessment of groundwater pollution in the Kathmandu Valley, Nepal. *A Report on Joint Nepal-Australia Project,1996.*
4. Metcalf & Eddy, I., 2003. *Wastewater engineering: treatment and reuse.* New York: McGraw-Hill.
5. Miladinovic, N. & Weatherley, L., 2008. Intensification of ammonia removal in a combined ion-exchange and nitrification column. *Chemical Engineering Journal,135(1-2),* pp. 15-24.
6. Odjadjare, E. E. & Okoh, A. I., 2010. Physicochemical quality of an urban municipal wastewater effluent and its impact on the receiving environment. *Environmental monitoring and assessment, 170(1),* pp. 383-394.
7. Pant, B. R., 2011. Ground water quality in the Kathmandu valley of Nepal. *Environmental Monitoring and Assessment,* 178(1), pp. 477-485.

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